

ANALYSIS OF THE ADVANTAGES OF BIM IN CONSTRUCTION REHABILITATION

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To my Parents, Jordi and Imma and my brothers Maria, Montse and Jaume.

Live as if you were to die tomorrow. Learn as if you were to live forever

-Mahatma Gandhi

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ABSTRACT

Up to this date, the construction sector has barely integrated technological innovation and progressive management, being one of the sectors with low level of productivity and competitiveness compared to the rest of the industrial sectors.

This is a common characteristic in all countries, which is surprising due to the economic and social importance that construction has. Until this moment, the traditional methodology of development and management of the construction process did not facilitate the incorporation of sufficiently effective tools to reduce the degree of uncertainty, nor increase the reliability and accuracy of compliance with the objectives in terms of time, cost and quality.

Therefore, the need to modernize the construction industry was more than evident, demanding a qualitative leap to a global digital environment, allowing to cover the entire life cycle of a project (from its beginning to its demolition or change of use), promoting the integration and collaboration of all the agents involved in the process. This change in the execution of the projects can be achieved with the new methodology called BIM (Building Information Modeling).

However, despite the apparent growth in the adoption of this work tool, it is necessary to understand that there is a large number of people in the construction sector who are not yet informed about new technological advances, and, therefore, are opposed to this new methodology, defending the traditional one.

This work aims to inform about the general aspects of BIM and the benefits it brings in the construction sector, as well as the numerous applications available. In this work, the emphasis will be placed on the advantages of this new methodology applied in the rehabilitation sector.

Six practical rehabilitation cases were studied, citing the benefits of this new methodology for each of them. You can see with these cases, the numerous applications that BIM system has for this sector. It can be used as a tool to detect errors, thus saving material and labour costs, since it is not the same to detect it in the design phase than in the execution phase. Also, as a visual tool to understand the project in a way closer to reality. Also, avoid misunderstandings with the different agents working on the same project since all work with the latest update of the project thus avoiding the current errors of the traditional system, which must be constantly correcting and modifying the plans for lack of communication...

Currently, the biggest problem of buildings and construction in general, are the "unforeseen". That many times, they are simply lacking foresight. As a solution to these unforeseen events, this BIM methodology is born, which allows for more information, more quantifiable data of the building. And the more data we can give the project, we can get more accurate information and closer to reality.

The main difference with the traditional methodology is that it gives top priority to the information. Many times, with the traditional system the final cost of the project is more expensive than expected and several times is because the company or person who calculated it, did it wrong. It did not take into account all the data, did not take into account all the necessary information unlike this new methodology.

In any case, the BIM serves to better manage the design and construction of a building.

All this information will be complemented with a practical case, to demonstrate in a practical way the advantages of using this new methodology. The Revit program will be used, with which I became familiar from the first weeks at the beginning of the present work.

KEY WORDS: CONSTRUCTION REHABILITATION, BIM, REVIT, BIM IMPLEMENTATION

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ABBREVIATIONS

BIM- Building Information Modeling

CAD - Computer aided design

2D - Bidimensional

3D - Tridimensional

4D – 3D + Fator Tempo

5D – 3D + Fator Tempo + Custos

6D – 3D + Fator Tempo + Custos + Sustentabilidade

7D – 3D + Fator Tempo + Custos + Sustentabilidade + Gestão de Instalações

IFC - Industry Foundation Classes

IPQ - Portuguese Institute of Quality

ONS - Organization of the Sector of Normalization

COBie - Construction Operations Building Information Exchange

BEP- Bim Execution Plan

MIPD -Model Information Delivery Plan

FEUP- Faculdade de engenharia da universidade do Porto

INTRODUCTION

1.1. CONTEXTUALIZATION

In recent decades, computer capabilities to represent and analyze three-dimensional models for buildings have increased significantly.

Lately, the appearance of the BIM methodology (Building Information Modeling), has made possible the transition between an industry that based its projects on a drawing that was carried out through computer-aided design, to a new way of carrying out projects based on the administration and in transference of industry centered on information.

In order to understand the context in which BIM tools have emerged and their importance in this field, first of all it is necessary to carry out a preliminary analysis of the construction sector, which will allow us to understand the need to apply a new system.

Several factors stand out, promoting and conditioning the emergence of a new system of project implementation.

In the last decades, the civil construction sector has had the lowest level of productivity of all sectors, which is justified by the lack of coordination between agents, and project stages, lack of adherence to new technologies that accelerate the information flow, some informality and lack of employee capacity. In addition, there is a lack of understanding about the importance of operating costs of an infrastructure at the time of design. That is, it is not designed with maintenance in mind, even though operating and maintenance costs represent 80% of the total lifetime cost of an infrastructure, and only 20% correspond to the design and construction.

In this context **BIM (Building Information Modeling)** appears as an alternative to a new system, to carry out projects both in new constructions and in the rehabilitation of existing buildings.

1.2. MOTIVATION OF THE PROJECT

Over the last few years there has been an increasing popularization of the BIM method. A survey by the NBS (National Building Specification) in 2015 in the United Kingdom for construction professionals, the "NBS National BIM Report 2015", indicates that the adoption of this technology increased 13% in 2010 and 48% in 2014, with 77% of respondents agreeing with the statement that BIM is the future.

The evolution of the awareness and use of the BIM is illustrated with the following figure:

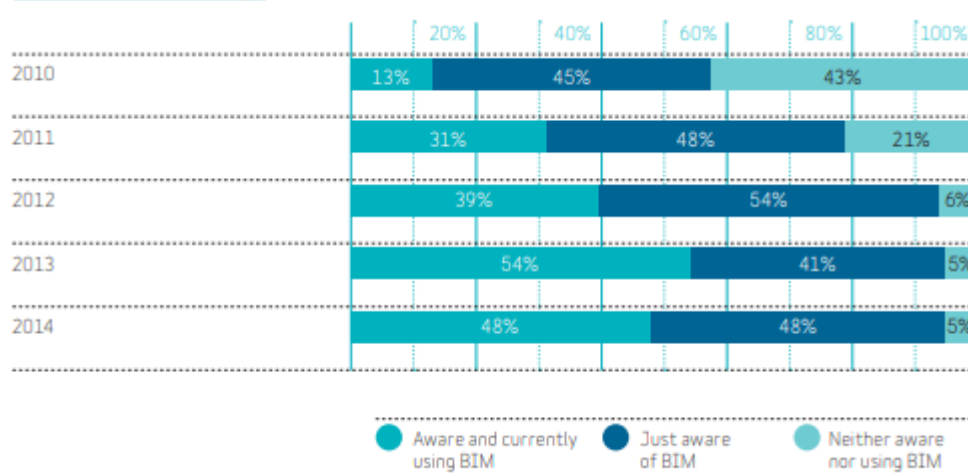


Fig. 1 A survey by the NBS (National Building Specification)

However, despite the apparent growth in the adoption of this work tool, there is still a long way to go, as it is necessary to understand that there is a large number of people in the construction sector who are not yet informed about new technological advances, and, therefore, are opposed to this new methodology, defending the traditional one.

One of the reasons that led me to develop this project was, as has been observed, the growing momentum this new way of working is having, and, therefore, as a future worker in this sector, it was a way to gain knowledge about working methodologies such as the BIM. I was able to study the benefits offered by this methodology and, at the same time, tried to develop the theme so that all people who are interested in the subject can study it.

In addition, from what I have noted as a result of the extensive study that has been carried out for this project, there is a great deal of information on the BIM methodology, in contrast to the limited documentation on the benefits that BIM provides quantitatively in the construction sector, especially in rehabilitation, so there is no methodology to evaluate its benefits. In addition, most study projects are confidential and therefore only part of the main idea or conclusions can be drawn.

Therefore, this work aims to collect all useful information that has been obtained from numerous sites and be able to present a conclusion on the subject, which will be supported by a case study.

1.3. OBJECTIVES OF THE PROJECT

This work aims to inform about the general aspects of BIM and the benefits it brings in the construction sector, as well as the numerous applications available.

In this work, the emphasis will be placed on the advantages of this new methodology applied in the rehabilitation sector.

This article also details the various ways you can get a model using existing technology tools, and then learn how to extrapolate the information and work on BIM.

Six case studies will be individualized and the advantages of using the BIM methodology will be specified. In some of them, empirical data will be compared with the use of the traditional method.

Thus, with this project it is proposed to carry out the analysis of the benefits that BIM offers in rehabilitation, based on a broad search of information.

All this information will be complemented with a practical case, to demonstrate in a practical way the advantages of using this new methodology. The Revit program will be used, with which I became familiar from the first weeks at the beginning of the present work.

1.4. STRUCTURE OF WORK

This work consists of 5 chapters:

Chapter 1: As an introduction, the current construction sector situation will be addressed, and the objectives of this work will be stated.

Chapter 2: It will be explained what BIM all about is, and what are its biggest advantages, in particular, the many useful tools that can be used to carry out a project in this industry. The situation of the BIM in the world will also be exposed, and how its evolution is predicted.

Chapter 3: The use of BIM in the field of rehabilitation will be specified. In this chapter we will first study the different ways of getting the model needed to start any project and then extrapolate the information obtained to work on BIM. Then, six case studies will be detailed about how the use of the BIM methodology has brought benefits in buildings for rehabilitation. This chapter also describes a summary of the advantages and disadvantages of using BIM in the rehabilitation sector, through the study of the six cases, as well as all the information gathered in articles, web pages and thesis.

Chapter 4: a practical case will be made from the Revit program; a 3D model will be obtained with all the indicated reforms and the necessary information to make a budget. The personal advantages of the Revit program compared to the AutoCad program are described. As well as those benefits that the program contributes in this sector.

Chapter 5: conclusions of the project, answering the question whether it is beneficial to use BIM in rehabilitation buildings.

2

BIM

2.1. BIM DEFINITION

BIM (Building Information Modeling) is a collaborative work methodology for the creation and management of a construction project. Its objective is to centralize all project information in a digital information model created by all its agents.

BIM assumes the evolution of traditional design systems based on the plan, since it incorporates geometric (3D), time (4D), cost (5D), environmental (6D) and maintenance (7D) information.

The use of BIM goes beyond the design phases, encompassing the execution of the project and extending throughout the life cycle of the building, allowing the management thereof and reducing operating costs.

[1]

The acronym BIM is composed of three words with their respective meanings:

- **Building:** informs us of the object on which the methodology is based, extending its use not only in building works, but also in rehabilitation, civil works and other possible projects. Not only does it consider the design process, but it also includes a process that begins with the same conception and design of the project, continues with its construction and exploitation and ends with the reconversion of this, that is, participates in the entire life cycle of the project. [2]
- **Information:** information means all the useful information generated during the entire life cycle of a building, such as: plans, construction details, 3D views, technical sheets, structural calculations, facility calculations, energy calculations, measurements and budgets, work planning, use and maintenance documents, etc. [2]
- **Modeling:** in this concept a great part of the utility of the BIM methodology resides, since it works in a single model that can be used by those agents involved in the project. This characteristic is obtained thanks to the possibility of being able to export the models in standard formats compatible with other computer tools, highlighting mainly the files in IFC format. [2]



Fig. 2 words that relate to bim (<https://enriquealario.com/bim-pequena-escala/>)

This methodology allows coordination among all the agents involved in a project, thus having all the information coordinated and updated in real time. BIM allow to unify or link the architectural modeling of a building with the rest of the systems that complete the project, such as facilities, structures, topographical studies, measurements and budgets, planning, energy efficiency studies, etc.

BIM representation softwares allow drawing and creating elements, with their specific dimensions and characteristics (physical, technical, commercial, maintenance, etc.) unlike the traditional system that designs a model by representing lines and geometric figures that represent elements architectural or construction, reflected in two-dimensional planes.

2.2. PROBLEM SOLUTIONS AND BIM OBJECTIVES

BIM system arises from the need to solve a series of current problems¹ when executing a project, such as:

- Lack of dimension of a project.
- Lack of definition in the facilities.
- Collisions between construction elements.
- Last minute modifications by the promoter.
- Optimistic provisions without having suppliers.
- Lack of supplies of materials.
- Lack of human resources.
- Lack of coordination among building agents.

The following is a summary of BIM's main objectives²:

- Improve visual presentation (3D), allowing to quickly understand the idea of the project and its dimensions or, as well, a tool for marketing assets.
- This methodology can be used as a support to a variety of decisions, establishing criteria for choosing alternatives when making investments, comparing the functionality, scope and costs of the solutions, for later calculate returns.
- Evaluate the best constructive solutions based on environmental parameters through energy efficiency studies in the project design phase.
- Facilitate feasibility studies of the construction, quickly obtaining the estimated costs incurred by the project and the planned construction periods.
- Use of the project data of the building during the execution works, as well as in the subsequent phases of exploitation and maintenance.
- Reduce costs, there is a study that ensures to achieve the different savings in terms of costs:
 - o Project cost savings: 30%
 - o Under construction: 22%
 - o In Maintenance of 18%

¹ The problems are described in the conference held by 'el colegi de arquitectes de Catalunya' [3] and on the reference page [2].

² The objectives are exposed in several pages referenced [2] [4] [5]

- Improve quality.
- Improve work safety.
- Improve risk control.
- Reduce project modifications.
- Reduce number of incidents.
- To allow a better exchange of data in real time in a coherent, precise and complete way, that is, it works with interoperability, improving aspects such as efficiency and effectiveness, as well as allowing the detection of errors more easily.

2.3. CHARACTERISTICS OF THE BIM

One of the most interesting attractions of the BIM methodology is its precise geometric representation of the parts of a construction (building, industrial plant, power plant, etc.) in an integrated data environment, whose related benefits³ are:

- Each designed part is referenced with data (properties and specifications) of product and features to perform automatic calculations or detect interferences automatically.
- It allows quick simulations of each design proposal, allowing the selection of innovative, effective and efficient solutions.
- BIM allows to measure and calculate the costs during the useful life, and the environmental sustainability of the property that are the most demanded requirements by public administrations and private clients.
- It has a common database that allows governments, industry, and manufacturers to operate more efficiently since it is easier to share information, analyse it over time, and reuse it.
- In BIM it is only necessary to model the objects once for all the project documentation, since they are automatically derived to the plans, views, etc., that are required, with the added benefit of avoiding interferences and differences.
- The precise and realistic visual representation in 3D and 2D of the different proposals improves the explanation of the projects to the clients and other interested parties.
- Life cycle data (requirements, design, construction and operational information) can be used in the management of projects for planning, execution, maintenance and dismantling.

These described advantages allow a higher quality in the work developed, since part of the time that previously could be spent in the preparation of plans can be devoted to a greater purification in the design.

2.4. HISTORY OF THE BIM

In 1961, Dr. Patrick J. Hanratty, helped develop DAC, one of the first computer-aided design graphics.

In the 80s, Autodesk launched AutoCad, which represented a revolution in the design sector for architects and engineers, offering greater efficiency and productivity as an alternative to pen and pencil. [7]

³ The benefits are exposed in several pages referenced [4][5][6]

The pioneering company in the application of the BIM concept was the Hungarian company Graphisoft, which implemented it under the name of Virtual Building since 1987 in its ArchiCAD program, recognized as the first CAD software for personal computer capable of creating both 2D drawings as 3D.

Autodesk began using the BIM concept in 2002 when it bought the Texas-based Revit Technology Corporation, while others postulate that it was Professor Charles M. Eastman of the Georgia Tech Institute of Technology who first disseminated the concept of building information model, as a synonym of BIM, in the early seventies in numerous books and academic articles.

However, there seems to be a generalized consensus that Jerry Laiserin was the one who popularized it as a common term for the digital representation of construction processes, with the aim of exchanging and interoperationalizing information in digital format.

This technology is offered today by different companies such as: Nemetschek, Sigma Design, Autodesk, StruCad by AceCad Software, Bentley Systems, Graphisoft, among others. [8]

2.5. BIM CURRENTLY

Some European countries have already started a series of strategies to implement, progressively, the use of BIM in the drafting of projects, their material execution and their subsequent maintenance. Several countries have started the implementation of BIM in high budget public buildings to achieve their optimization. [6]

2.5.1. EUROPA

Currently BIM has a period of strong knowledge especially in Europe:

- In the **United Kingdom**, the use of BIM was introduced as mandatory in 2017, since it considers that it improves delivery conditions and minimizes costs compared to the traditional system. The United Kingdom wants to be the pioneer of the use of this technology in the field of construction to make projects more efficient, profitable and productive. [10]
In a survey that can be found on the page of www.building.co.uk [9], very positive results were obtained for this technology. It can be said that the use of BIM works and meets expectations obtaining good performance and productivity:
 - More than six in 10 (62%) respondents now use BIM, compared to 54% in last year's survey.
 - Of the companies that do use BIM, most are convinced of the benefits: 70% say that BIM will help reduce costs, while 60% believe that BIM will help save time.
- For its part, **Scotland** also demanded as mandatory from April 2017 to carry out with BIM any project with a cost of more than 4 million pounds. [13]
- In **France**, the government began to integrate the BIM officially from 2017 onwards in more than 500,000 homes and obliges its use for projects of more than € 20M, although it will soon become compulsory for all projects. [12]

- In **Germany**, it is more the private client that demands BIM, in fact, it is 90%, a demand higher than that demanded by the government, which does not require a BIM migration in public projects. [10]
- The **Netherlands**, in 2012, established the BIC (Building Information Council) to disseminate and implement its use. In 2015, 76% of the works were carried out at BIM, from the design phase to maintenance. [10]
- In **Portugal**, they are still promoting the insertion of BIM in the construction industry. The entities IPQ (Portuguese Institute of Quality) and ONS / ITS (Organization of the Sector of Normalization) oversee the diffusion and implementation of BIM.
A Technical Commission was created with this same objective, which describes the guidelines and norms to achieve good use and application in projects. Currently, the BIM system is not well established.
There are groups like BIMFORUM Portugal that try to bring BIM closer to the business world, promote debates and conferences about the benefits and way of working that BIM presents. [14]
- In **Switzerland** since 2017 there is an Open BIM Guide that helps users to develop their projects in the BIM methodology with standards and regulations. [10]
- **Italy**, the use of BIM is required for any project that exceeds 5 million euros. [13]
- The **Scandinavian** countries were the precursors in the adoption of this methodology, so it is mandatory, and they have already experienced the improvements in the first person. [12]

2.5.2. REST OF THE WORLD

The main countries⁴ that use BIM:

- **EE UU**, they have been pioneers in this methodology since 2003 with their National Program 3D-4D BIM and have been expanding BIM for years in large public projects which have different BIM protocols according to their states, different routes and standards for the life cycle of a building. On the other hand, in Canada it has not been until 2015 that he has imposed BIM standards in his government.
- Since 2014 **Australia** and **New Zealand** offer a BIM guide for planning, transport and infrastructure, consultants and contractors. They have also made public that in 15 years all projects must be done in BIM.

As for the easternmost countries:

- In **Dubai**, the use of BIM is mandatory since 2013.
- **Singapore** has a BIM guide route that aims to standardize the industry from 2015, which stipulates the use of BIM for projects of more than 5000 m2.
- **China** has also developed a BIM Guide in a National Plan and in 2014 they have already developed a BIM implementation strategy, where in 2019 it is expected that 30% of the projects will be carried out under this standard. Hong Kong and Taiwan lead the BIM migration.

⁴ The information is searched in the referenced pages [12] [13].

- All public projects of more than 50M \$ in **South Korea** are BIM compulsory since 2016. The government has been promoting BIM projects since 2010 and require their use for projects over 50 \$ M.
- And in **Japan**, this year 2017, 46% of companies have already worked with the BIM methodology.

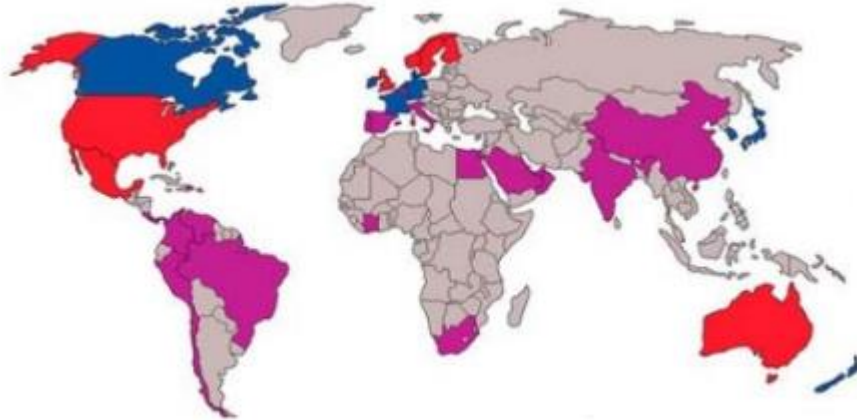


Fig. 3 Map with the main countries that use BIM. In red, Pubic Projects. In violet public and private initiatives and in blue BIM guides (<http://www.grupovalero.com/valero-primer-fabricante-eps-nivel-nacional-generar-productos-bim/situacion-bim/>)

2.5.3. SPAIN

In Spain, the BIM methodology has been used for a long time, both in the design phase and in the execution phase, mainly in the field of building. However, until now they have been isolated cases and have gone unnoticed by most. These projects were carried out in high-budget public buildings.

In the same way there are more and more centers that promote their dissemination, such as university schools and vocational training centers. Although the main disseminator of this methodology is BuildingSmart Spanish Chapter. [6]

The interest that BIM arouses in Spain, is increasing in the architecture and engineering professionals and in the academic field, a test of it are the numerous congresses that are carried out on it.

In Spain, currently, singular and large-scale projects are the ones that capture the maximum attention with respect to the use of BIM, but already there are many projects of smaller magnitude that, both in public and private works, are carried out through this methodology.

In 2018, those public infrastructures with budgets over 2M €, must be made in BIM in the phases of Design and Construction in new construction. By 2020, they will be for all phases, including maintenance and both for new construction and rehabilitation. [13]

Currently, more than 50% of international clients of Spanish construction companies demand or have an interest in the use of BIM, it is essential to access tenders, contracts and collaborations for Spanish companies and professionals who want to participate in construction projects, reform, installation, and operation in the US UU., United Kingdom, Central and Northern Europe, Arab Emirates, Asian Southeast, China or Australia. [6]

2.6. REPERCUSSIONS OF BIM

The use of BIM is expanding; therefore, the training offer is increasingly complete and competitive.

A study establishes that 65% of the architects who have already used BIM have received a positive ROI, which is an indicator that ensures that the project is profitable.

In fact, some firms that are already using this methodology not only prefer BIM for 3D but also for the visualization and management of documentation, among many other benefits. However, and according to a study by Autodesk, there is still a certain distrust on the part of companies (especially the smallest ones) to make the leap towards this methodology since there is no obvious study of expenses and return on investment.

The following is a survey carried out by SEEDstudio in 2017 on the benefits that BIM produces for companies that use this type of methodology. [6]



Fig. 4 Impact of the use of BIM in the main countries

2.7. THE FUTUR OF BIM

The BIM methodology continues in continuous expansion. Therefore, it is foreseeable that in the future their capacities will increase considerably. According to Barcelona Building Construmat, a hall of the construction sector, the BIM market will grow 19% this year worldwide. [16]

More and more innovative experiences will continue to connect BIM with information and communication technology solutions applied directly to construction, such as: virtual reality and augmented reality, geographic information systems, the use of drones, incorporation of robotics to the constructive process, the management of urban infrastructures, its applicability to the management of Smart Cities or 3D printing in small and large scale. On the other hand, the consolidation of standard exchange formats will allow for a more fluid collaboration between the agents and will make possible the generalized implementation of on-line integrated project management systems. [6]

There will be more BIM users as the new methodology is known and implemented and the benefits that it entails will be observed. The United Kingdom, which is the maximum promoter of BIM carried out a study presented in NBS National BIM report BIM and that is illustrated with the following image, where

you can see the increasing number of users for this new methodology in the United Kingdom in the next years. In other countries, its use will also increase as its use becomes more widespread. [17]

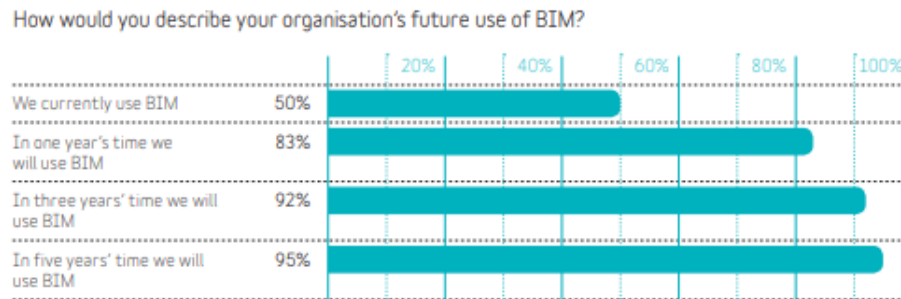


Fig. 5 Study presented in NBS National BIM report BIM

2.8. IMPLEMENTATION OF BIM

The wide possibilities of the BIM methodology and its complexity make necessary a progressive, coordinated and orderly implementation, for which it is necessary to have clear references, such as standards, guides, protocols, technical instructions and bases that facilitate it. Of these instruments will depend, to a large extent, that the implementation can be carried out in the most effective and efficient way possible.

The implementation of BIM will cause an impact on the organization and the productive and or administrative processes of these. As the organization begins to implement the BIM, it is important to explain clearly to all those involved, the changes that will occur in the organization, as well as the new processes and technologies that will be applied. The implementation of BIM must be supported by the organization. This means that there must be permanent support from all the parties involved. [18]

Some of the problems and challenges that are identified when implementing BIM include: the lack of understanding of the true scope of the technology, the lack of trained professionals and technological training programs suited to the needs of the industry, the differences of interest and capabilities among the different disciplines of the industry, the lack of competition among software suppliers, the lack of a culture of digital standards, the legal gaps regarding the use of BIM as a contractual document, and the low public support for innovation technology in this sector. [19]

The development of BIM implementation strategies is taking place at very different speeds in different countries. Countries such as Korea, China, New Zealand, Australia and the United Kingdom stand out as the main disseminators of this methodology.

The implementation of BIM in Spain is composed of Top-down and Bottom-up strategies, which are information processing strategies characteristic of the information sciences, especially in relation to software. For this case: [21]

- **Top-down:** development of initiatives from the public sector with impact on the private sector. They have opted for this dynamic BIM countries like the United Kingdom and Singapore.
- **Bottom-up:** development and improvement of these initiatives from the private sector with impact on the public sector. Australia has chosen this option as a strategy to implement the BIM.

As mentioned above, in the current framework there is a great diffusion of BIM Guidelines and standards (both nationally and internationally) that allow us to compile a BIM strategy at the organizational level, depending on the level we want to reach and the resources of the BIMs. that we want to have. They are all displayed on the Building Smart page, which is one of BIM's main disseminators both internationally and nationally. [20]



Fig. 6 Strategies Top-Down and Botuum up (<http://www.esbim.es/en/faqs/>)

To achieve a correct implementation, it is necessary to highlight and highlight three points:

- BIM vision
- Leadership
- Gradual change

2.8.1. BIM VISIÓN

An essential factor for a successful implementation of BIM is a concise and well-managed vision by the executive leaders on the benefits that the adoption of the BIM processes will bring to the company.

To implement BIM successfully, organizations need a strategy that addresses their business needs and values in a specific way. To effectively obtain the benefits of using BIM in the projects, the people with greater authority in the company must make all the necessary efforts, to position the BIM within the strategic objectives of the organization. For this, we recommend some guidelines to achieve it [18] :

- The vision must have sufficient scope and aspirations to unite all the agents of the organization, since otherwise the necessary impetus will not be produced that will allow generating a change and consequently implementing BIM in an appropriate way in the organization.
- The highest authorities of the company must be formalized about BIM in order to know the impact and spread to its employees the benefits of working with this new methodology. A suitable start may be to have the support of a reliable advisor who provides guidance on the best way to define and execute the vision.
- The creation and programming of clear objectives helps to cope more adequately with the initial uncertainty that implies starting with a new method. By realizing these objectives, a climate of trust is generated on the new system and helps all the personnel involved to be more motivated to continue with the new process.
- Define and answer questions such as: what, where, when and why, will provide each part of the organization with the real details you need about BIM.

2.8.2. LEADERSHIP

For the implementation of a pilot project, it is preferable to have a BIM leadership team. This team should encourage the vision of BIM to be reflected in work methodologies that can be put into practice to produce the desired results and performance in line with the strategic objectives of the organization.

In any organization, the management of lasting and sustainable changes can be a difficult task that requires the adaptation of strategies of each organization. Here are some management tactics [18]:

- A communication plan by the highest authorities demonstrates to all those involved, the commitment of the organization with the implementation of BIM, transmits confidence to all the agents involved and allows to shorten the distance between theory and daily practice.
- BIM adoption requires the adoption of new skills and new ways of working by the organization. This makes it necessary to invest in training to ensure that the right people are available for new projects.
- The BIM methodology represents a significant change of traditional processes, which must be addressed from the beginning with those involved in the project so that there are no misunderstandings or errors when carrying out the project with this new method.
- Project reviews allow the BIM leadership team to evaluate the initial measures and the effectiveness of BIM technology, standards and processes in the pilot project. These teams can detect errors, improve standards and processes, and apply best practices.
- Measurement of BIM maturity. It is preferable that the BIM leadership team determine key indicators to measure the progress of the organization, in terms of the overall objectives and milestones indicated in the vision

2.8.3. GRADUAL CHANGE

Once all the adjustments of the previous points have been made, the choice of a pilot project is pertinent. This pilot project may be based on fictitious projects, real projects, parts of projects, among others. All options are valid, and the choice will depend on the level of admissible risk and the labor available to carry out your current job. The implementation of a pilot project should include measurements at all the key stages, to really understand if BIM is being implemented correctly and if it is having the projected impacts. The positive benefits received by each person involved in the project during the process must also be documented for purposes of calculating the return on investment.

It is probable that in the early stages of the implementation of a pilot project there is a fall in productivity, mainly due to the need to train people involved in the new processes of the organization.

During the change to BIM, positive support is required from the administration and relevant personnel. It is also necessary to establish the correct expectations from the beginning of the process, formulate an action plan and guarantee the level of adequate training of the employees. By starting at a small scale and building trust, and by increasing essential skills and experiences, the transition to BIM will accelerate with each new project. [18] [19]

2.8.4. LEVELS OF THE BIM

The Levels of BIM was a concept created by the United Kingdom, which defines the different states that must be produced to work in an integral and collaborative way with the BIM systems. It is necessary a gradual change, in which new ways of working are assimilated little by little, as well as becoming familiar with the new technologies offered, both softwares and hardwares since, a sudden change can harm the operation and result of a project. Therefore, a series of implementation rules that form the levels of BIM development were established [5]:

Level 0

At this level, it corresponds to the type of traditional methodology work. Each one of the agents that participate in a project elaborates its own documentation, therefore, there is no type of collaboration. The designs are represented in two dimensions and the method of communication and presentation is based on paper or printing plans. The program used is the AutoCad. [5] [22]

Level 1

At this level, there starts to be a little collaboration, but it is not clear or continuous between the different disciplines and agents that participate in a project. We find a mixture of 2D and 3D work with CAD softwares. The purpose of drawing in three dimensions is to be able to show the projects in a more visible and understandable way, to obtain a clear conceptualization of what is being drawn. On the other hand, the 2D documentation, basically plans and details, makes up the documentation of the project from a more technical and functional point of view, in the first instance, obtaining the license and, subsequently, executing the established. [5] [22]

Level 2

Level 2 is characterized by the introduction of collaborative work in the work methodology. All agents work with CAD tools or even BIM, but not all of them work on the same shared model. All or part of the information and design documentation is shared through a common or different type of file, but which allows any agent to use it. [5][22]

Level 3

Finally, Level 3 is characterized by collaboration and interoperability between the different participants of a project. It is known as Open BIM and is characterized by developing a unique model that is shared by a server accessible by any agent from anywhere. With the reach of this level it will be possible to work the entire life cycle of a building, finally reaching the Integrated Practice or Integrated BIM. [5] [22]

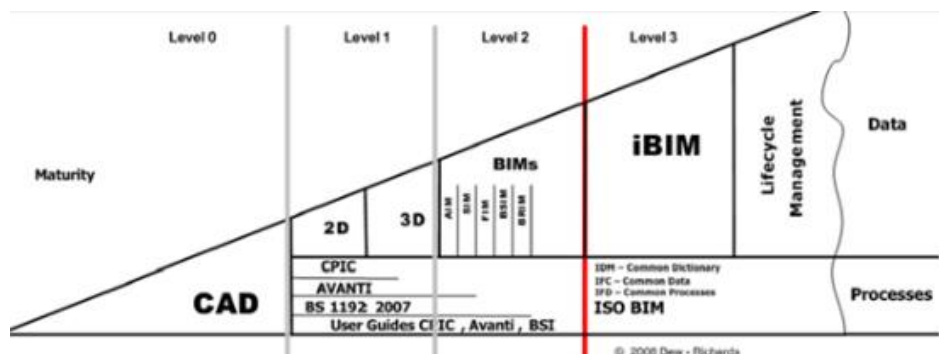


Fig. 7 Levels of the BIM (Foto: <http://jguillen07.blogspot.pt/2015/11/niveles-de-madurez-y-dimensiones-del-bim.html>)

2.9. DIMENSIONS OF BIM

The life cycle of a BIM project starts with an idea and ends with the demolition and, if possible, with the recycling of the project. This cycle can be divided into the seven phases that have been called the BIM dimensions [23]:

1D Idea	We start from an idea and we define the initial conditions, the location, some first estimates are made (surface, volumetry and costs), the execution plan is established, etc.
2D The sketch:	Preparation of modeling software; definition of materials and structural and energy loads. The bases for the sustainability of the project are established.
3D Building information model	Based on all the information collected, the 3D model is generated, which will serve as a basis for the rest of the project's life cycle. It is more than a graphic representation of the idea. The 3D model is not only visual but incorporates all the information that will be needed for the following phases.
4D Scheduling:	To what until now could be considered something static is given the dimension of time. So that the phases of the project are defined, a temporary planning is obtained; as well as simulations of temporary parameters, life cycle, sun, wind, energy, etc.
5D Estimating:	It deals with cost control and estimation of project expenses. The main objective of this dimension is to improve the profitability of the project.
6D Sustainability:	Sometimes called Green BIM or green BIM, it consists of simulating the possible alternatives of the project to finally reach the optimal alternative. And all this before 'placing the first brick'.
7D Facility management applications:	It could be said that it is the manual that must be followed during the life of the project, once built, for the use and maintenance of this (inspections, repairs, maintenance, etc.)

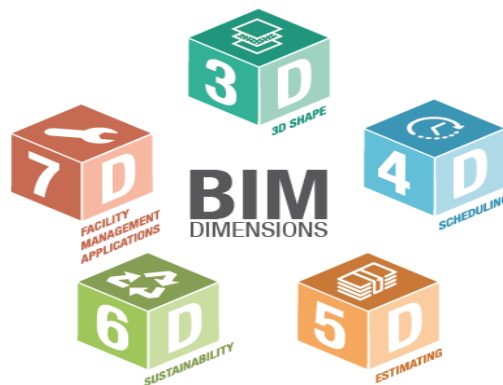


Fig. 8 BIM dimensions (<http://biblus.accasoftware.com/en/bim-dimensions-3d-4d-5d-6d-7d-bim-explained/>)

2.10. STAGES OF A BIM PROJECT

Throughout its life cycle, construction projects go through three main phases: Design, Construction and Operations. These phases are subdivided into sub-phases that in turn are subdivided into activities, sub-activities and tasks. [24]

Design phase	Construction phase	Operations Phase
Conceptualization, planning and cost estimation.	Programming and workshop plans	Occupation and operation
Architectural, structural and facilities design.	Construction, manufacturing, purchases and supplies	Asset management and installation maintenance
Analysis, definition of detail, coordination and specifications	Start-up, as-built and delivery	Complete dismantling and reprogramming

Table. 1 Stages of a BIM project

All BIM projects are developed in three stages that will be explained below:

2.10.1. Stage BIM1: Modeling based on objects:

In Stage 1, users generate uni-disciplinary models, in any of the three phases of the project life cycle: Design, Construction or Operations. These models are mainly used to automate the generation and coordination of 2D documentation and 3D visualizations. In this stage, basic data are also exported (for example: listing of doors, measurements of concrete, furniture costs, accessories and equipment ...) and light 3D models (ex: 3D DWF, 3D PDF, NWD, etc ...) [24]

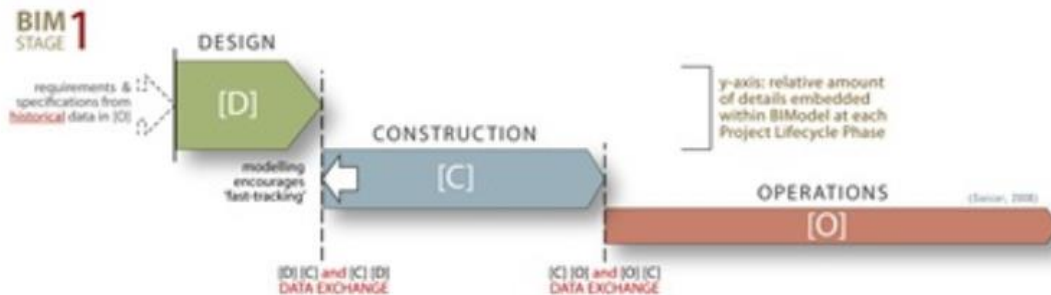


Fig. 9 Stage BIM1: Modeling based on objects (<http://www.bimthinkspace.com/2008/11/effects-of-bim-on-project-lifecycle-phases.html>)

As you can see in the previous image shows how the project follows a linear process. However, as we move closer to stage 2, the design and construction activities will tend to overlap, saving time.

2.10.2. Stage BIM 2: Collaboration based on the model:

Once a broad modeling experience has been developed in Stage BIM 1, the agents involved in the design phase collaborate with those of other disciplines.

Technologically, collaboration can occur in many ways, depending on the BIM software tools selected by each participant. [24]

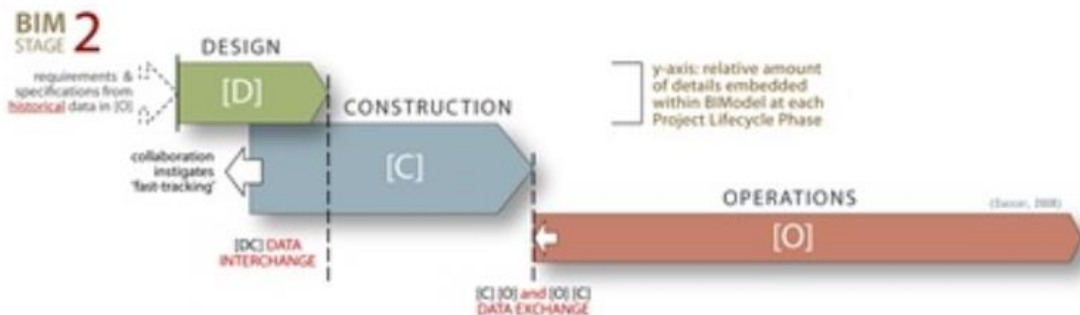


Fig. 10 Stage BIM 2: Collaboration based on the model (<http://www.bimthinkspace.com/2008/11/effects-of-bim-on-project-lifecycle-phases.html>)

2.10.3. Stage BIM 3: Integration in the network

In this stage, integrated models are created that are shared and maintained collaboratively, throughout the life cycle phases of the Project.

This is where network-based integration encourages concurrent construction, a term used when all project activities are integrated, and all aspects of design, construction and operation are planned simultaneously to maximize the value of the objective functions, At the same time, the constructability, operability and safety are optimized. [24]

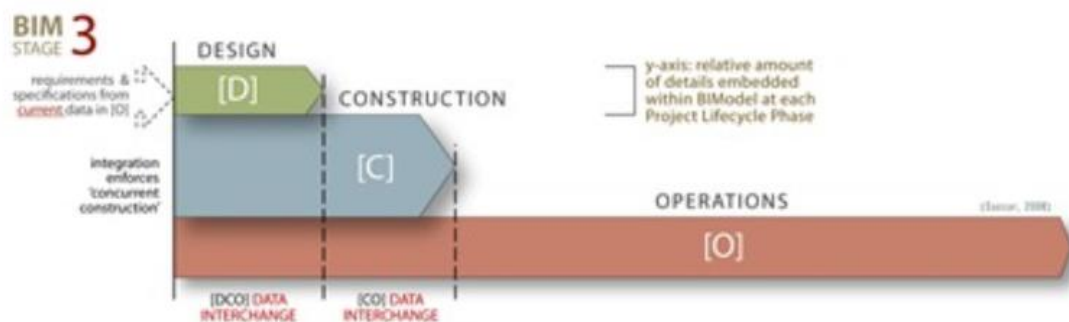


Fig. 11 Stage BIM 3: Integration in the network (<http://www.bimthinkspace.com/2008/11/effects-of-bim-on-project-lifecycle-phases.html>)

2.11. ROLES IN A BIM PROJECT

In this section, the roles and responsibilities will be defined throughout the life cycle in a BIM project.

To manage a project with BIM methodology (BIM Project), a task team is created in which the roles and responsibilities in the BIM Execution Plan (BEP) are defined and will be reflected in the contract. In the management of a BIM project the roles are not positions in the company, they are functions and responsibilities assigned in the work team.

Next, the different roles that intervene in a BIM project are detailed, both BIM users and in other activities derived from the BIM methodology [25]:

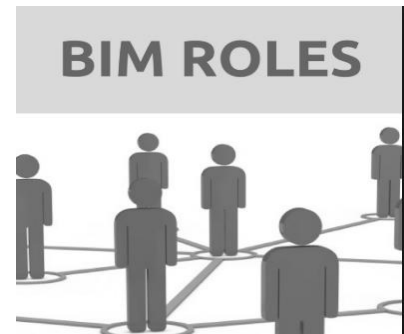


Fig. 12 BIM roles
(<http://www.bimbarcelona.com/roles-bim/>)

OWNER /CLIENT	It is the person or organization that decides to start up and finance the BIM Project and for that purpose it contracts the services of the Project Management Team, EGP (Project Management Team, PMT), forming part of the Collaborative Environment (Common Data Environment, CDE).
BIM PROJECT MANAGER	Person appointed by the client to lead the BIM project team, manage the BIM project, and achieve the objectives so that the client's expectations are met.
INFORMATION MANAGER	It is the agent responsible for managing and controlling the flow of information among all the agents involved in the BIM project throughout all phases of the project's life cycle. It is responsible for everyone to have the right information at the right time. Manages the transmission of project information to the Promoter or Client.
BIM MANAGER	Lead the correct implementation and use of the BIM methodology, coordinating the modeling of the project and the resources in collaboration with all the agents involved, ensuring the correct integration of the models and their disciplines with the global vision of the project, also coordinating the generation of contents, with the ability to communicate the benefits and difficulties of BIM.
LEAD DESIGNER	He is the one who manages the design, including the approval and development of the information. It is who confirms the design results of the Project Design Team, EDP (Integrated Design Project Team, IDPT).
LEAD CONSTRUCTION	He is the one who manages the direction of the execution through the corresponding managements with BIM systems, including the approval and development of the information. It is who confirms the results of the execution of the Construction Team, CT (Construction Team).

TASK TEAM MANAGER	It is responsible for the production of the design and all the elements that relate to a specific task. These tasks are often based on disciplines that have to be shared by the entire team, there being a head of disciplines that responds to the director of Design Management.
BIM ANALYST	It carries out analyses and simulations based on the BIM model: it analyses the performance and performance of the building, simulates the circulations of the building, carries out safety analyses and analyses the energetic behaviour.
CAD MANAGER	Ensures that CAD models are integrated into the project using the agreed standards and methods. This role should be the responsibility of the CAD Coordinator (CAD Coordinator).
BIM APPLICATION DEVELOPER	Develop and customize the software to support the integration of BIM processes.
IFC SPECIALIST	IT Professional who contributes, together with experts in different areas of the AEC / FM industry (architecture / engineering / construction / Facility Management), to the IFC format and to the initial definition of the requirements of the IFC extensions
BIM FACILITATOR	It helps other professionals, not in the operation of the software, but in the visualization of the information of the model. It helps the engineer's work to communicate with contractors. It helps the FMs to extract information from the BIM models with different purposes: asset management, space planning, maintenance, planning etc.
BIM CONSULTANT / BIM EXPERT	It offers guides for projects of designers, developers and builders for the BIM implementation in large and medium companies that have adopted this methodology and do not have experience as experts in BIM.
BIM RESEARCHER	Expert who teaches, coordinates and develops research on BIM.

Table. 2 BIM roles

2.12. DIFFERENCES USE TRADITIONAL SYSTEM WITH BIM

2.12.1. PROJECT PHASES IN TRADITIONAL SYSTEM

The traditional methodology follows a linear workflow. Every project starts with the collection of documentation about the project. Once all the necessary information has been obtained, **the drafting of the preliminary** draft begins, a phase in which the fundamental aspects of the general characteristics of the work are exposed (functional, formal, constructive and economic).

The different proposals are represented in plans, mainly elevations and plan views and the best alternative is chosen. Next, the **Basic Project** phase begins, which defines precisely the general characteristics of the work by adopting and justifying the solutions obtained. It is an insufficient project to carry out the construction, but it is sufficient to request the municipal license, which certifies the adequacy of the planned facilities to the current urban regulations and to the technical regulations that may be applicable.

During the elaboration of the Basic Project, the designer advances the drafting of the project to the point of needing collaboration with other agents: structural calculators, more specific property requirements, definition of facilities, location of public services, regulations applicable to the project ... The external agents to the design team receive the documentation elaborated to date by the designers, so that incorporating it into their models and work tools carry out their studies and design proposal. In this phase of the project there is a large amount of information and documentation that is not considered by all the agents at the same time. That is, the linear flow of work is constantly interrupted, where part of the work that had already been done by one of the parties is necessary to be modified.

Each modification is a huge job on the part of most of the parties. Great efforts are being made and a very controlled monitoring of the documentation and decisions taken during the execution phase is required.

Finally, we reach the third phase called the **execution project**, which is the only project that, prior to planning approval, authorizes to start the execution of the works once approved by the City Council.

[5] [26]

2.12.2. SOLUTION OF THE PROBLEM RAISED WITH BIM

As it has been observed in the previous point, the traditional methodology presents a certain level of uncertainty regarding the control of execution periods, control of budgets and achievement of the final quality of the project. In addition to the workflow is not linear, there are many interruptions caused by not having the latest updates of plans or due to the constant changes that are made ... As a solution to these problems BIM appears, which provides more reliability and precision in the estimation of costs, terms and result for the following reasons [6]:

- For its ability to generate more consistent, more accurate project documents and in less time.
- For the improvement that it implies in the collaboration and coordination between the different intervening agents during the life cycle of the project.
- Due to its relationship with other collaborative management methodologies, such as Agile Project Management or Lean Construction, and with those that cover the entire life cycle, such as Product Lifecycle Management (PLM).

The emergence of BIM has led to a new way of approaching projects, as well as workflows. This technology allows generating and managing information through three-dimensional models throughout the life cycle of a project. On the other hand, this methodology allows us to share this information in a structured way among all the actors involved (architects, engineers, builders and other technical actors), fostering collaborative and interdisciplinary work.

It is necessary, then, a standard format that allows interoperability and the exchange of data in a secure manner, without errors and / or information loss.

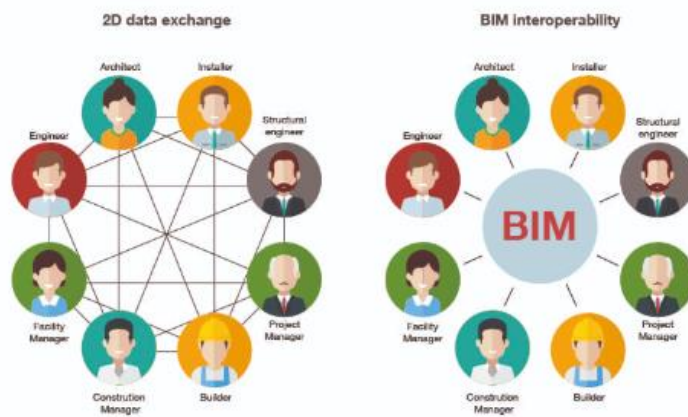


Fig. 13 differences use traditional system with bim (<http://biblus.accasoftware.com/en/ifc-whats-it-for-whats-its-connection-with-bim/>)

2.12.2.1. IFC (Industry Foundation Classes)

It is a data format that allows the exchange of an informative model without loss or distortion of data or information.

The IFC has been thought to elaborate all the information of the building along all his cycle of life, from the preliminary draft until the execution and his maintenance, happening through the distinct phases of design and planning.

Achieving complete interoperability between the various IT tools used by construction agents is very difficult to develop and achieve, since each program works with different computer codes, perfect communication between them being complex.

However, although today almost perfect interoperability between computer tools has not been achieved, a great saving of working hours and communication between the agents involved in the same project is obtained. The conversion of files from modeling software to IFC and is therefore imported into other calculation or dimensioning software, makes the projects acquire another level of efficiency and quality in their development stages, in the delivery of the model, creation of As Built documentation or even in Facility Management tasks. [27] [28]

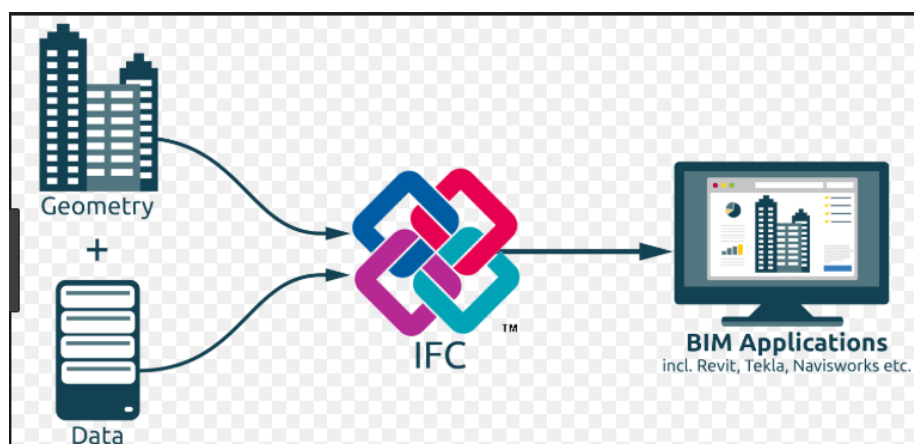


Fig. 14 IFC (Industry Foundation Classes) (<http://omniric.com/BIM-Building-Information-Modeling.html>)

2.12.2.2. COBie (Construction Operations Building Information Exchange)

Another way to transfer information data is the COBie files (Construction Operations Building Information Exchange), which have been developed together with IFC and to supplement it. The main objective of COBie is to facilitate and standardize the transfer of information from the construction project, from design, construction and Facility Management.

COBie is still in an initial development stage. Even so, several design and Facility Management software are already developing tools with COBie compatibility within their applications. As the most important document produced on COBie, a COBie code of practice was issued as a British standard in September 2014. [29] [30]

2.12.3. COMPARISON OF THE TWO SYSTEMS OF WORK

Apart from the differences explained in the previous points when working with BIM and the traditional system, it should also be noted that the factor that marks the difference between both is the time necessary to develop a project.

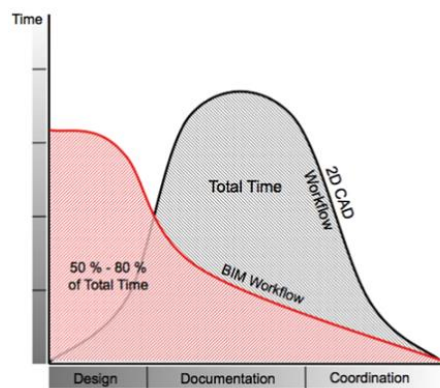


Fig. 15 comparison of the two systems of work (<https://www.arquiparados.com/t583-cad-vs-bim-quien-ganara-esta-guerra>)

As you can see in the image, in the BIM process there is a decrease in time from the first designs to the execution of the project, while in CAD it has the shape of a Gaussian bell, that is, it starts consuming little time in the basic one and it increases as we move forward in the project and then go back down quickly. [31] [32]

2.12.4. DIFFERENCES BETWEEN AUTOCAD AND BIM

The main differences between BIM and AutoCAD can be seen in the following table:

	CAD	BIM
DRAWING	Geometric elements/Constuctives	
	Lines, circles, polygons, solids, surfaces	Walls, doors, windows, roofs, grounds
Relation between plants, sections, elevations	They are independent entities, changes are made separately.	A single model, with any change is updated their respective planes.
Data of the elements	-	Properties of the elements (materials, costs, mechanical and energetic properties ...)
Reports	The calculations are made, and the information is extrapolated to work in other softwares.	Reports can be made automatically, also with the same file you can use the information to work with other softwares.
Team work	Little communication between members that causes misunderstandings and wasted time	All project members work with the same file that is updated each time. Therefore, everyone has the latest model of the project.

Table. 3 Differences between Autocad and BIM.

2.13. PROGRAMAS BIM:

In the market there are several BIM programs that we can use to apply them to architecture. Among them, three stand out:

- Autodesk Revit
- ArchiCAD
- AllPlan

Although there are other less prominent programs such as the following:

- Vectorworks: Like AllPlan, it belongs to the Nemetschek house. However, unlike AllPlan, Vectorworks has a Mac version.
- Microstation.
- ACCA Software.

When selecting the right program, several factors include: the price of the license, the compatibility with your operating system and the demand for use in the market, which will be given by the overall performance of the program.

It should also be noted that depending on the continent or the country, one or the other is used, for example, AllPlan is widely used in Germany while in the USA. is practically unknown.

Currently Revit is becoming the standard of BIM software as it did with Autocad, this is largely due to the good marketing of Autodesk rather than the quality of the program itself. However, the fact that it is

not compatible with Mac is one of its biggest disadvantages with respect to Archicad, its main competitor in this sector, which presents a very similar program with differences in terms of price (Revit is slightly more expensive) and use, Archicad has a little easier use.

There is an internal struggle that has been going on for years between Revit, Archicad and Allplan. We can see in the graph that finally Revit (in blue) is the one that at the moment is presented as the main program. [33]

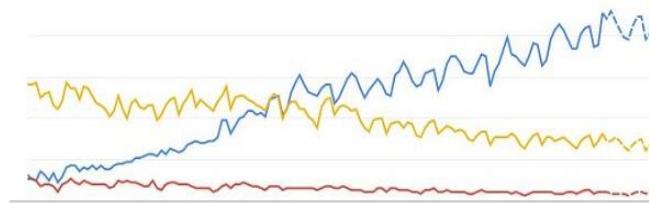


Fig. 16 Comparison about the most used programs. Revit (blue), Allplan (red) and archicat (yellow) (<https://www.arquiparados.com/t620-cual-es-el-mejor-programa-bim>)

2.14. CHARACTERISTIC FACTORS OF REVIT:

The main features of Revit are explained below:

- **EDUCATIONAL LICENSE**
Autodesk offers a free educational license of 3 years. This is very useful to become familiar with the tool, to train and acquire the necessary skills to be an expert in this software. Autodesk supports the student community by providing students, educators and institutions free access to 3D design software, learning tools, programs... [34] [35]
- **PROFESSIONAL LICENSE**
The commercial license offers several possibilities of subscription: monthly, annual and for three years. In this way, it is suitable for both small and large studios and each one can acquire the one that best suits their size and economic possibilities. [34]
- **NOT ONLY FOR ARCHITECTURE**
Some BIM softwares are unique and specially designed to design architectural models. However, Autodesk Revit also includes modules for facility modeling (MEP) and structures. [34]
- **PLUGINS⁵**
There are many plugins compatible with Revit, both free and paid. The five most used Revit plugins [34]:
 - IFC for Revit: allows to improve the export of our models allowing to adjust and customize many parameters. [36]
 - Archicad Connection: Allows the interconnection of Revit and Archicad [36]
 - COINS Auto Section Box: Indispensable for installations [36]

⁵ A plugin is an application that, in a computer program, adds additional functionality or a new feature to the software.

- Revit to Lumion: It allows exporting projects to Lumion which is a visualization program [36]
- Quick Select: allows to perform searches with a given criteria (types, parameters ...) either on the whole model or on a part of the previously selected model [36]

- **RESOURCES**

Another advantage of using Revit is the large amount of resources that can be found on the internet for this tool. On the one hand, most manufacturers have on their website family libraries (Revit objects) with their own products. There are also some reference websites with countless libraries of all kinds.

On the other hand, there is a large amount of training and support content around this Autodesk program. There is a wide range of courses, books, forums or Facebook groups in which to discuss the subject. [34]

- **INTEROPERABILITY WITH OTHER AUTODESK SOFTWARE**

It allows to connect with programs such as Dynamo for programming, Navisworks for management or Robot Structural Analysis for calculation of structures. It is also the best tool to move from Autocad to the BIM world.

In addition, it is also worth mentioning the good interoperability that it offers with other external softwares. [34]

- **MARKET**

Autodesk Revit is the most widespread BIM software used by companies. Although there is no updated data, according to some studies, the market share of Autodesk Revit is estimated at almost 50%. Therefore, it is the most demanded. [34]

2.15. BIM EXECUTION PLAN -BEP

BEP is the most important document of a BIM project.

It is defined as a plan that architects or engineers have to prepare to explain how modeling and information aspects will be carried out during the development of a project.

This methodology is already applied in those countries in which the application with BIM methodology is mandatory. In the British regulations, they differentiate this document into two parts. [37] [38]

I. PRE-BEP / BEP

It is the document prior to signing the contract with the client. The theory is that the client has delivered their EIR (employer requirements) to different agents that choose the offer. These agents prepare a PRE-BEP to demonstrate how they would execute the project in terms of BIM, in case it was awarded to them. [37] [38]

II. MIDP

The MIDP (Model Information Delivery Plan) is the post-contractual guide to express how the project will be executed in terms of modeling and information. [37] [38]

The use that is currently given to the BEP is Normative type or Guide for a work. The general sections are usually: [37] [38]

General information: inform why and what this project is for.	Project information Data related to the project.	Contact information Data of the agents participating in the project.
BIM objectives What is intended to achieve with this BIM model.	Staff and roles Organizational chart of the personnel that will intervene, roles and functions.	Process design Map and concretion of the processes of the way in which the model will be obtained with the different agents that participate in the project.
Requirements of the programs. Specification of the programs that will be used for the project.	Collaboration procedures. Meeting calendars, way of communicating to ensure a good preparation of the project.	Quality control Procedure to ensure that the established objectives are achieved.
Deliverables The files, formats and information that must be delivered are indicated.	Contract strategy. Strategies that allow to win more contracts / contests.	

Table. 4 General sections of BEP

2.15. CONCLUSION, CHAPTER 2

The BIM methodology has great advantages due to its numerous applications, from which the construction sector can benefit⁶ from:

- The use of BIM tools is not only linked to a single project phase or to a specific type of work, but is a set of useful tools throughout the project's life. This methodology allows the unification of all the linked agents, to create a collaborative working environment, since each of the participants contributes with an added value through their tools and working hours.
- BIM allows to create simulations that are very useful in all phases of the project: for example, the creation of constructive phase simulations allows, at first, to identify the possible conflicts of the project. In addition, such simulations allow us to check task compatibilities in a similar space-time and, at the same time, allow an improvement of the project performance.

⁶ The benefits and limitation exposed is a compilation of all the information that has been searched on the Internet plus the conclusions drawn by several referenced theses: [5][13][14][40][41][42][39]

- Best planning and organization of the tasks will be achieved, facilitating the administration of resources and the schedule.
- The BIM method also allows the extraction and updating of measurements. Each defined element will have its representation in the budget, incorporating its actual measures. Measurements can be lengths, areas and volumes in both gross and liquid values. This capability provides tremendous savings of repetitive calculations on the same measurements, by different professionals and companies in the same project.
- You can also get a budget as the project is updated. It is possible to define it in the early stages of project design, to detect possible errors and inconsistencies contained in it, to consult measurements and budgets of particular elements or different phases of the project, rapid changes in measurement and pricing.
- Nowadays, there are numerous programs for calculating measurements and controlling costs that can be linked through IFC files with the architecture model, such as Archimedes, Vico (Trimble), Presto, Medit (Autodesk), Arktec, etc.
- Within BIM tools, it is very important to distinguish between representation software and calculation and scaling software. The first, representation software, allows to obtain the design of constructive aspects, structures and installations. As mentioned earlier, the most representative in the world are the following: Revit, Allplan, AECOSim and ArchiCAD. But on the other hand, to size and calculate a structure, we will have to use other specialized software for this, having to link our models to such software. There are several ways to accomplish this link, so each team looks for the solution that best suits them, depending on the tools they use, according to their collaborators. Usually, in this case, it is very easy to turn the model into IFC format as explained above, and open it with the desired tool, although there are still incompatibilities with different programs.
- Nowadays, it seeks to make sustainable projects more environmentally friendly. Thus, according to the report of the IDEA (Institute for Diversification and Energy Saving), households will consume 17% of total final consumption, assuming at the same time 25% of energy consumption 38% electric. Because of this, the European Union has issued different directives to promote an improvement in energy efficiency as well as promote the use of renewable energy.

BIM is the methodology of technology and work that allows the construction industry to have greater control throughout the life cycle of a building, both in the energy efficiency of the buildings as in the consumption or environmental cost of our constructions and in the income of the use of renewable energy. Until now, running the power analysis with CAD programs was an impossible task and we had to divert ourselves to other external tools to perform simulations. BIM software, on the other hand, is able to integrate the technical properties of our materials used in the project. With the BIM tools, we can already carry out energy efficiency studies in the design phase in order to evaluate the best constructive solutions based on environmental parameters.

- Allows to anticipate decision making, because conflicts between building elements and even installations are predicted in the virtual model and before being built, thus reducing the impact which change would have in the later stages of the process.

As disadvantages or limitations, we find:

One of the main disadvantages focuses on the costs associated with the use of BIM, both at the software level and at the personnel training level for the use of this. The main existing softwares in the BIM market are paid and almost always have an annual subscription. The cost associated to the personnel that BIM requires in the current context assumes a fairly high monetary and training weight that only some companies can support.

One of the main limitations regarding the use of BIM is the difficult interoperability associated with it, this is quite noticeable when there are software preferences for the different specialties. So the architecture as each of the other design specialties usually use completely different softwares, which often appear many errors along the way and at the end of the process when these models come together.

Another limitation generally ignored is related to the type of hardware used in a certain industry and the relationship of this with the BIM software. It is necessary that BIM agents are equipped with computers with good specifications for the use of the software. It can happen that an excellent software that runs on a computer with few requirements leads to blockages, and the slow response, which will consume time and have the corresponding associated costs. Associated with this limitation is the slow real-time display of large-scale models in BIM software. This type of visualization is quite used in meetings that in the existence of slowness the various designers divide their model into different submodels which introduces additional modeling work, as well as design revisions in a divided way.

Another limitation associated with BIM refers to the fact that its terminology may contradict that used in traditional CAD processes. BIM requires familiarization with a set of expressions, phrases, nomenclatures that is unknown to professionals who work with CAD. Thus during the transition period there can be different interpretations and even deceptions between the different works and project.

Thus, we can conclude in this chapter that the BIM methodology has advantages in all phases of the project and for all the agents involved, being the best to obtain measurements, cost control, efficiency studies, visualization and project comprehension. Great importance is attached to the cooperation and collaboration that is established between the departments with which it is possible to unify all the information to obtain better coherence, since all the documentation of the project is contained in a single model, avoiding errors derived from different versions of the model and uses of different departments. All this allows an easy monitoring of the building's life, leading to a good reduction of costs and time spent.

Its implementation is therefore unavoidable. However, to achieve this, there must be commitment and willingness on the part of all stakeholders, because this methodology integrates many disciplines and many actors intervene in it.

BIM IN THE REHABILITATION

3. INTRODUCTION

BIM can be used both in construction of new building and civil works plant and in rehabilitation projects, changes in use, restoration of heritage, maintenance, etc. The digital data collection combined with the BIM methodology can provide great improvements in accuracy, cost savings and times in all types of construction projects.

Our objective with this work is to observe if the BIM system is also suitable in the rehabilitation of buildings and to make an analysis of the different advantages and disadvantages of the use of BIM in this branch of construction.

The BIM creation process can be different between "new buildings" and "existing buildings" due to the variation in the quality of the building information, the availability of the information and the functionality requirements.

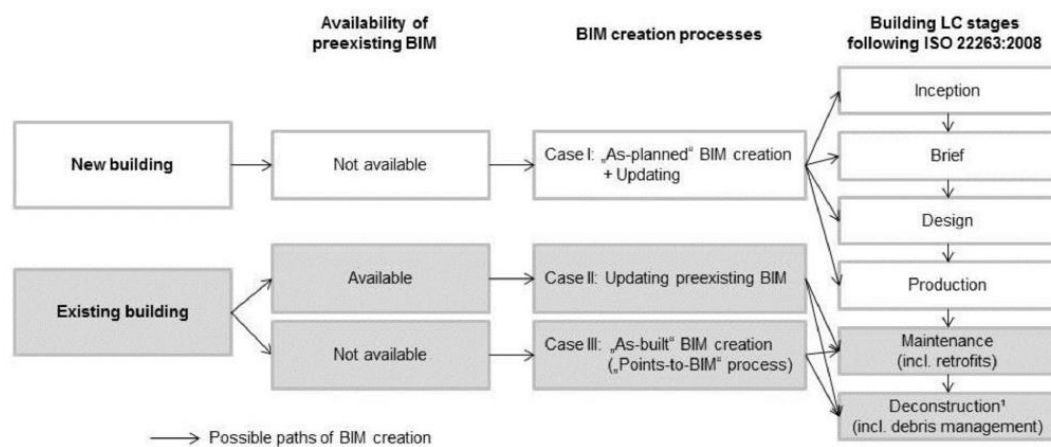


Fig. 17 BIM model creation processes in new or existing buildings depending on available, preexisting BIM and LC stages with their related requirements
(<https://www.sciencedirect.com/science/article/pii/S092658051300191X>)

To work with BIM in existing buildings it is necessary first of all to achieve modeling. Currently to achieve it, the following 3 steps are necessary:

- Data processing:
- Object recognition
- Modeling

3.1. DATA PROCESSING:

There are different ways⁷⁷ to obtain the modeling of a rehabilitation project based on information from the current state of the building. Many times, graphic information is already available, such as:

- Modeling already in 3D.
- 2D vector plans (Dwg, Dxf, dgn ...)
- Vector drawings in PDF
- Paper plans

3.1.1. WAYS TO OBTAIN A MODEL WITH INITIAL INFORMATION

3D Modeling

By having the BIM model of the building, information is available on all types of files in the ifc format, files in the BIM program that ensures that all the objects generated by a platform can be read on other platforms, that is, it has universal files.

Currently it is not very common to obtain information in BIM, but increasingly there are companies that provide this information in this type of language. A practical example is the Camp Nou, when a rehabilitation was proposed, a company performed its modeling to carry out a rehabilitation project.

The main advantage is that you can work directly, since there is all the information of all the elements identified as category, type and family. So, with this type of information you can directly make all the variations to get the new project of rehabilitation of the building.

2D vector plans (Dwg, Dxf, dgn ...)

With this kind of information, when you import them into the modeling programs, you cannot work on them or edit them. In this way, to obtain its modeling together with the information of each object that is drawn, it is necessary to trace over the AutoCAD file, to obtain the new figure in BIM files and with the respective bibliographic references in order to obtain the information tabulated in detail.

Plans in PDF

Depending on the program used, the information is exported in different ways. For the Allplan program in the same way that vector drawings in 2D, as you could do in Autocad, you can import pdf files into the modeling program with the advantage that in this case you vectorize each object with a reference, either circles, lines ... therefore, the objects are editable, since the reference is not external. In the same way as 2D, therefore, to model it, it will be necessary to trace the drawing and document all kinds of elements that appear. In the case of Revit, you first need to pass the pdf to image.

Plans on paper

With this type of information, you must first scan the documentation to be able to work with the image and thus be able to treat it. In this case too, once the image is imported, the drawing must be traced to obtain its modeling.

⁷⁷ All the different ways of obtaining a model have been obtained from a conference held by the Col·legi de Arquitectes de Catalunya. [43]

3.1.2. OBTAINING MODEL WITHOUT INITIAL INFORMATION

If in this case we do not have any type of building information that needs to be addressed, there are several possible solutions:

- Traditional method
- Laser Scanner

Traditional method

It consists of making a sketch with the measurements that are obtained in the work through tools such as tape measure, laser meter It is a very slow and not very precise method since, if any measure is missing, it is necessary to return to the site. Also, it is not a good method to obtain measurements in difficult to access sites and also, the information you treat cannot be used to perform directly in BIM, but you have to perform one of the methods explained above.

Solutions to this problem through the following programs:

1. The **On-Site Survey** and **On-Site Photo** programs have been developed specifically for projects and rehabilitation works, reform and interior design, valuation and real estate asset management. These programs allow the digital capture of data in-situ and the survey of premises, facades and buildings, facilitating work, avoiding errors, reducing time and displacements and allowing a quick and reliable estimate of execution costs.

The drawings and the generated model are exported, already drawn, to the design and drawing systems, BIM and CAD (Allplan, AutoCAD ...) [44]



Fig. 18 Operation of On-Site Survey (<https://www.arquitectes.cat/es/escolasert/campus-profesional/jornada-tecnica-allplan>)

2. **Laser scanner:** It is a technique that is gaining more strength thanks to the fact that more and more companies are turning to the BIM system. It consists of generating an infinite number of points, using lasers that generate a series of point files that will be discussed later. Once these point files have been processed, a series of information necessary to define the current situation of the building is obtained, recreating the real scenario with total accuracy. It is a very useful technique for rehabilitating facades, building old buildings without the necessary documentation to start rehabilitation, etc.

Once the model is already developed, you can work with several design tools, such as, for example, Revit. [45] [46]

Advantage:

- Fast process. A scan lasts about 5 'with a capture volume of about 900,000 points per second
- Very accurate.
- Low invasive and reach difficult to reach sites
- Integrated photogrammetric 3d camera, offers an image that allows us to move as if we were there. [43]

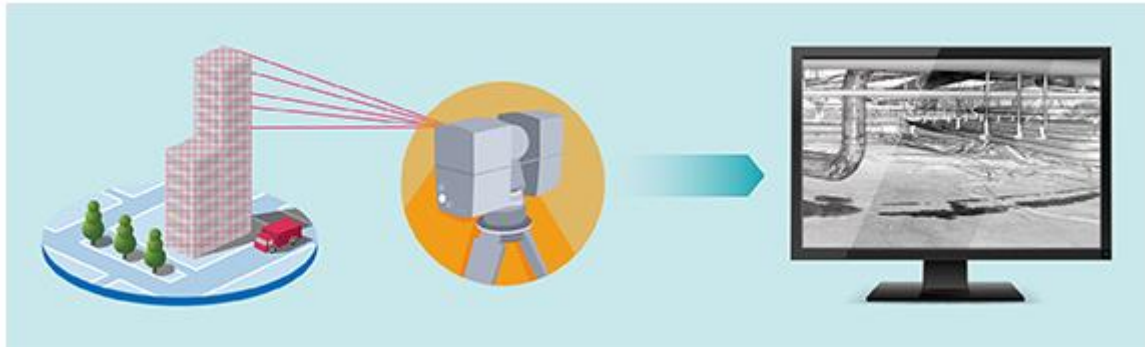


Fig. 19 Laser scanner (<https://www.deerns.com/services/modelling-services/integrated-bim-3d-building-scan>)

3.2. RECOGNITION OF OBJECTS

The captured and processed construction data is used to recognize building components and their relevant characteristics for the required functionalities. The object recognition methods and tools differ due to the geometric complexity of the required building and the applied capture technique, the data format or the processing time.

This information is not yet automatically recognized in buildings and requires intense data entry and user interaction.

3.3. MODELING

Modeling involves the creation of BIM objects that represent building components, including geometric and non-geometric attributes and relationships. That is, the 3D survey of the building. The more information you enter in the program closer to reality, the property will be and more details and information will be available. Documentation needed to understand the building and make the necessary changes in its rehabilitation.

It is true that, in order to model in existing buildings, qualified personnel and great efforts are needed in the investigation of automated data capture, processing and modeling. But once the model is achieved, it reduces the costs of building audits and increases productivity in BIM maintenance and deconstruction processes.

3.4. BENEFITS OF BIM IN A REHABILITATION CONSTRUCTION

The use of BIM in rehabilitation presents a series of advantages. Of these advantages most are already described in chapter 2, the most notable in this case are: [47] [48][49]

- Integrate all the information of a building (geometry, construction systems, materials, facilities, measurements, budgets, etc.) in a single model, which allows choosing the best strategy according to the pathologies that arise in each case of rehabilitation and allows reconstruct the construction stages with all the information materials and techniques used.
- Access to all information at any time and place and allows to better understand the behavior of the building and choose the best benefits for the present injuries.
- Visualization of the 3D model of a building that has to be rehabilitated / restored helps to make better project decisions on aspects such as volumetric, distributions, structural strategies, facilities, materials, budgets and work phases.
- The BIM facilitates communication with the different agents involved (developers, planners, builders, industrialists and maintainers) and the understanding of the scope of the work, direct measurements, viewing of project options, etc.
- Study the different phase alternatives and choose the one that best suits the operational and economic criteria.
- BIM modeling guarantees the dimensional coordination of the plans, the efficient management of changes and the automation of work
- Carry out a much more delicate thermal analysis due to all the characterization information of the material and the structural and construction systems that the building collected and introduced into the model.
- Allow detection of thermal bridges and overcome them.
- Be able to offer more specific and efficient solutions in each sector.

As it has been observed, there are many advantages to apply the BIM System in rehabilitation, even so, there are many companies that do not know it due mainly to the inability to adapt to new emerging technologies, caused by resistance to change. Without considering the advantages that it entails. One of the main advantages is time, since it minimizes interference with operators, personnel from other sectors and maximizes the profitability of the project.

Many of them are also reluctant to use this technology due to its price. Currently, where the BIM is not established in our society (Spain), it supposes a higher cost since, we must add the price of the software that will be used to generate the projects plus the training of all the agents involved. You also have to add the price of a good antivirus for computers. One of the problems with solution that we can find with BIM and that have emerged in recent times are cyber-attacks, which, BIM to be a digital system is also prone and therefore could stop the progress of the work or eliminate everything what has been working so far. [50]

3.5. CASE STUDIES TO ANALYZE BIM

According to an article from the University of Arizona, one of the most appropriate ways to analyze the benefits of a technology is through case studies, since it is possible to analyze, in first hand, the evolution of the project phases, as well as their problems and solutions. The objective of this chapter is to analyze several case studies in order to draw conclusions about the benefits that the use of BIM methodology can offer in the rehabilitation of buildings, compared to the traditional methodology that is currently operating in this sector. As a result of the study of several articles and web pages, there is a lot of information about the BIM methodology, in contrast to few documentations on the benefits that BIM provides quantitatively in the rehabilitation sector, and there is no methodology to evaluate its benefits. In addition, most projects are confidential and therefore only part of the main idea or conclusions can be drawn.

The study of the cases began with the reading of a large amount of bibliography already written, analyzing the information currently available on considerations of the possible advantages provided by BIM found in articles or web pages. A conference held by colleges of Catalonia architects, where was given some opinion on the BIM methodology in rehabilitation projects, was also taken into account. From this conference, we were able to extract the main idea, since it lacked documentation, practical and empirical for what were subjective conclusions about their experience with this new methodology.

Making comparisons between cases is difficult, since most construction companies do not use a formal methodology to evaluate their benefits. In addition, the benefits obtained differ between the interested parties. For example, contractors derive better coordination and productivity as benefits, while architects see improvements in design programming, estimating, and processing.

Several case studies were analyzed, two of them extracted from academic articles:

- As built case studies for BIM as conflicts detection and documentation tool [51]
- How to measure the benefits of BIM — A case study approach [54]

Another case study comes from a thesis from the engineering university of Porto:

- Implementation of the BIM Integrated Information Model

And the remaining cases were found on web pages.

There will be an analysis of each of the cases, highlighting the advantages that working with BIM has meant for each one of them. You can also see the different uses of BIM according to the type of project.

3.5.1. CASE 1

The following case study is exposed in the academic article: As case studies built for BIM as a tool for detecting and documenting conflicts. [51] In this article, is first explained the importance of information management in buildings and the benefits that BIM brings in different fields, which will also be reflected in this work. And the second part of the article is based on the analysis of a practical case about how BIM can be useful as a tool for detecting conflicts between construction documents and reality.

As an introduction, the article explains the importance of information provided by an existing building as a basis for all changes, modifications or other. It serves as an information source to avoid the excessive cost of work delays and correction during the phases of operation and maintenance or renovation.

Many problems emerge in the management of existing buildings throughout their life cycle due to the lack of technical information. Besides, the traditional documentation method does not manage the development and renovation of buildings.

With the BIM methodology, these obstacles can be transcendent with the collaboration of all the interested parties in the different phases of the project's life cycle to insert, extract, update or modify the information.

Apart from this, as it has been mentioned on many occasions in this project, BIM has the potential to create a unique model that offers better visualization, allowing the detection of conflicts that appear in the different phases of the project and the ability to extrapolate all the information of the intervening elements.

This article explains the BIM's benefits as a tool for detecting conflicts between reality and existing schemes. Moreover, with the BIM, both, model and 2D plans are updated as the necessary variations are made, opposed to the traditional system that does not have tools to manage the constant changes in project buildings.

Also, BIM's ability to re-document an existing building in order to improve the production is very important, because it reduces costs and time, which are a feature that is increasingly being built up, as we mentioned before, that was a factor of lack of productivity.

A major cause also emerges a large number of professionals who work in different parts of the project (structure, services, design, distribution,) following a fragmented management method. If the information is not accurate, the next steps will be affected, and it will be common the documentation absence with the traditional methodology.

The construction industry verified that the traditional process, which all the projects were carried out, was a great waste of data, while the BIM methodology allows to insert, extract, update or modify information in a collaborative way with people who work on the project.

Other benefits of using the BIM methodology mentioned in this article are that it also integrates an innovative platform to improve productivity and sustains the construction of the project's life cycle.

The three essential elements (social, economic and environmental) contribute to the sustainability of our way of measuring or the level of sustainability of our projects.

The BIM can improve social sustainability in main areas:

- First, it provides better design of facilities for the comfort of a society's life. The BIM allows you to review the project through visualization of a three-dimensional model of construction information (3D) before the installation is built.
- Second, the BIM changes the execution of the conventional practice project, which is very fragmented, in order to achieve a better collaboration between the involved agents that facilitates the strength of the relationship at work among the participants of the project. On a BIM platform, the team members share their own visions of information with other members to form a reliable basis for decision-making. In terms of economic sustainability, a system of estimating costs

based on BIM has been created to automate the production of a quantitative list, how it is explained in the article: “Analysis of the first Polish application of cost estimation based on BIM” [52]

- Improving the environmental sustainability during the construction of life cycles through the green BIM, where we can find more information next article: “Enhancing environmental sustainability over building life cycles through green BIM A review”. [53]

This article carried out two case studies: the central library and a multipurpose hall of the Diyala University in Iraq, where in last years, it has been in constant wars and, thus, many heritage buildings and old were destroyed.

The objective of this project was to use the BIM to document and visualize these buildings in 3D, providing their modelage. This work is part of a project that aims to keep and protect heritage wealth in Iraq.

At the moment of the modeling visualization of these buildings, it can observe numerous inconsistencies between the documents that were created for the construction of the building and its final result. Thus, in this case, it can be observed that BIM is used as a tool to identify errors made in the traditional way.

One of the several examples, which are explained in the article to better understand the situation, is the following one:

In one of the plans it was not mentioned that there was a different level in the plant, while when performing its modeling in BIM with the Revit program that difference was immediately identified. In this way, it's possible to see the potential of BIM due to 3D visualization. At the initial time of the building construction, they found a problem, giving as a solution some stairs that later were not documented, since it meant repeating all the plans and therefore a great waste of time.

With the use of BIM, we can observe that it is possible to update the modeling and obtain plans each time there is a variation, saving time. The problem is explained visually through the following image:

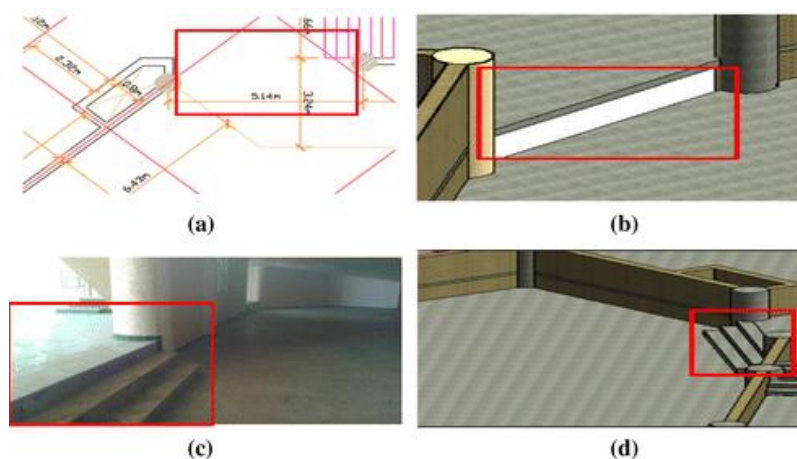


Fig. 20 Example of the case exposed in the article. [51]

Of all the errors detected, the following conclusion is obtained: it was found that precision through the BIM technique had an error rate of 6.646%, while the traditional estimation method revealed an error rate of 43.739% in terms of document congruence with reality.

The following figure demonstrates the formula for each line of adjustment of the two methods. It is a comparison of the differences obtained between the traditional system and BIM and reality.

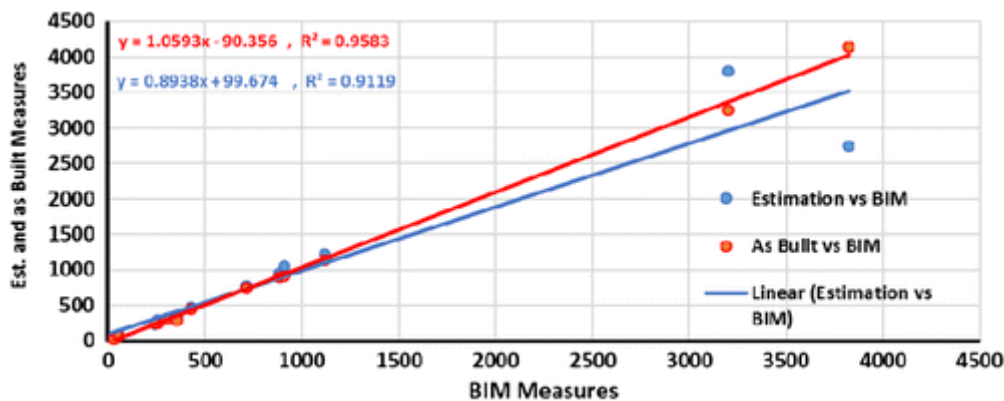


Fig. 21 differences obtained between the traditional system and BIM and reality [51]

With this image, we can see the high precision of BIM measures in comparison with traditional estimates.

The knowledge obtained in this study is that the inclusion of BIM as an error tracking tool has proven to have a great impact on the accuracy of project documents, therefore, BIM has utility in reducing drift in the management of construction information.

With this study, it is clear the applications variety that BIM has in the field of construction, in this case, as a tool for information management in the built projects.

The BIM has proven to be a powerful tool for the re-education of existing buildings and the detection of conflicts, but also to reduce changes in new or continuous projects.

3.5.2. CASE 2

In the article "How to measure the benefits of BIM - A Case Study Approach"[54], from Arizona State University, is presented a study to develop a methodology to analyze the benefits of BIM. The model was based on different real case studies with similar characteristics and scales, implementing in some of them the BIM methodology and in others the traditional system.

The objective of this work was to obtain empirical data of the projects carried out with and without the BIM methodology, to determine if their use could be beneficial in construction projects.

This article began with the study of a lot of initial documentation. Existing information on the possible advantages provided by BIM was analyzed with the following objectives: to determine appropriate measures for the evaluation of the benefits of BIM and search for results or information of the measurement parameters used in a variety of projects. Of all the great information extracted, only a few sources contained some quantifiable results based on case studies on the advantages of BIM.

This article exposes the difficulties that exist in the moment of measurement of the construction projects, being a challenge the quantification of changes and benefits. Typically, KPIs (Key Performance Indicators) are used, which are indicators of productivity.

In this article, we have chosen as benefits to analyze the work schedule, change requests, Request For Information (RFIs) and construction cost. An order of action was used to quantify the benefits of using BIM, which was as follows:

- Establishment of measures or KPI to collect and quantify the costs and benefits of BIM.
- Verification of measures between case studies, especially those projects that do not use BIM methodology against those that use in the same organization to minimize variables.
- Evaluation of the information resulting from the case studies to quantify the benefits and costs associated with the use of BIM.

On the other hand, FMI Management Consulting and the Construction Management Association of America (CMAA) have stated the main challenges and difficulties in assessing benefits in the information systems business can be categorized into six areas:

- Some of the benefits may be intangible.
- Organizational changes may occur as a result of introducing a new system.
- Business benefits evolve during the system life cycle.
- Several agents involved will evaluate the system subjectively and may have conflicts in their respective opinions.
- Users may feel intimidated or coerced by the new system and may negatively affect their work.
- Difficulties of use, such as improper use.

In the construction industry, are considered as almost tangible benefits the productivity, availability of information, etc. As intangible benefits can be counted the best risk management, competitive advantage and good access to the market.

Intangible considerations are difficult to quantify in monetary terms, since their analysis are prone to subjectivity and estimation. So, the information they can provide is basically supportive. Several pages and articles highlight the lack of methodology to estimate its benefits.

The case study is based on a company that sought to increase its efficiency and opted for the use of the BIM methodology for the execution of electrical, mechanical, hydraulic and structural installations. The work consisted in developing 3D models in parallel with 2D models, the latter acting more as a complement than as a substitute. The 3D models were used in three specific functional areas, those that represent the most complex equipment and installations. The company decided to use BIM strategies in 2001 and also used in subsequent projects, so a good database was available, both current and historical, which allows us to make a correct comparison between systems.

Three case studies were used, where the measures developed under the traditional methodology were compared according to the BIM methodology, in order to obtain possible benefits for the business with the use of BIM. Due to company confidentiality requests, economic values are not shown in the article, but they allowed the results to be reflected in percentages and also the different conclusions emerged in the study.

In **case 1**, special attention was paid to returns, comparing two historical projects carried out in the same company using traditional methodology with two other projects with BIM methodology. The results obtained were as follows:

Case 1 – returns from Non-BIM to BIM.

Metric	Unit	Non-BIM	BIM	Δ (Non-BIM vs. BIM)
RFIs	Quantity/tool	6	3	3
Change orders	% of standard project costs	12%	7%	42%
Schedule	% behind standard schedule	15%	5%	67%

Fig. 22 Case 1 Returns from Non-BIM to BIM [54]

It can be observed that the data show a positive differential or a gain in projects made with BIM.

For **case 2**, we focused on investments based on a project developed during the study that used BIM and the traditional methodology in the same three functional areas discussed above. The results were:

Case 2 – investments from Non-BIM to BIM.

Metric	Unit	Differential (Non-BIM vs. BIM)
<i>Design costs</i>		
A&E costs	% of total awarded design scope	31%
3D background model creator costs	% of total awarded design scope	34%
<i>Construction costs</i>		
Contractor costs	% total awarded construction scope	(– 5%) (savings)
<i>Design + construction costs</i>		
Overall savings with BIM in design and construction	% total awarded design and construction scope	(– 2%) (savings)

Fig. 23 Case2 Investments from Non-BIM to BIM [54]

It can be observed that the design of BIM causes an increase in costs, while saving costs thanks to the use of BIM in the construction phase. In order to estimate by the contractors, two requests for offers in two different formats were requested. On one hand, they asked them for the total expected cost of the scope of work to be carried out on electrical, mechanical, water and sanitary installations, in case of carrying out the project under the traditional system and, on the other hand, the cost of the project of each of the mentioned areas of action, developing the project under the methodology BIM. In this way, it was possible to compare the budget between the two methods.

Finally, Case 3 considers returns and investments focused on a single functional area, based on two previous projects carried out without the BIM methodology with two other projects already executed in the BIM methodology. Being only one of the functional areas of the project (not researched by the company) allowed to make an accurate comparison between the different ways of executing the project. The company achieved cost and benefit savings as a reward for its effort to use the entire BIM methodology. The results can be reflected in the following table:

Case 3 – returns from Non-BIM to BIM.

Metric	Unit	Non-BIM	BIM	Δ (Non-BIM vs. BIM)
RFIs	Quantity/tool	2	3	- 1
Change orders	% of standard project costs	23%	7%	70%
Schedule	% behind standard schedule	15%	7%	53%

Fig. 24 Case3. Returns from Non-BIM to BIM [54]

In addition, the team responsible for the study in question conducted different interviews and surveys with professionals dedicated to Project Management and other technical coordinators with the objective of providing an individual perception and evaluating the experiences and the general environment of the work carried out under the BIM methodology. The results were positive for the use of the BIM methodology, as well as the empirical data of the investigation.

3.5.3. CASE 3

This practical case is in the thesis developed at the Faculty of Engineering of the University of Oporto (Faculdade de Engenharia da Universidade do Porto): “Implementation of the Integrated Information Model of BIM”.

In this report, a survey and analysis of the two types of methodologies is made to draw a conclusion on the benefits of BIM.

First, a study was made where an online survey was carried out to observe the various complications from various projects and different companies to observe or identify those parts of the project phase where there were more complications and, thus, to think about the most appropriate methodology to perform this project.

A large number of justifications was obtained, more precisely 6445. In the table, we can see the most common conflicts that appear when carrying out a project and which has been observed in the other cases of study:

Justification	Nº Cases	%
Incomplete execution projects	318	4,9
Lack of rigor in execution projects	2776	43,1
Incompatibilities between projects	575	8,9
Mismatch of projects to the needs	181	2,8
Alterations derived from budget variations	101	1,6
Modifications to the order of materials	853	13,2
Modifications suggested by employees about the project	126	2,0
Corrections in the work	57	0,9
Unforeseen circumstances	689	10,7
Other causes	769	11,9
Total	6445	100

Table. 5 Common conflicts that appear when carrying out a project

As can be seen, 57% of the problems emerge in the design phase, with 43.07% lacking precision in this phase of the project corresponding to the cases studied. This is due to the main problem that has been mentioned several times about the disadvantages of using the traditional system. As the BIM methodology is implemented, these numbers will decrease. From this study, it was decided to carry out the project using BIM methodology.

This case study consists of the rehabilitation of an upper passage for pedestrians located in Águas Santas /Palmilheira, belonging to the Minho railroad line. The objective of this project was to improve the conditions of this passage with BIM.



Fig. 25 rehabilitation of an upper passage for pedestrians located in Águas Santas /Palmilheira

On this way, for the thesis, the BIM project was carried out with the help of ProNic⁸ and Revit as a solution to these incompatibilities (Previously commented) and to draw conclusions about the advantages offered by this new methodology compared to the traditional system.

The result obtained in this thesis, reaffirmed the advantages of using modeling supports, such as Revit, in comparison to AUTOCAD, since it observed a considerable saving of time thanks to its software which allows the identification of each element with a category and the extraction of a table with all elements with their respective descriptions and costs.

Moreover, with the model, it was better understood, highlighting the conflicts and possible inconsistencies which appeared in the reform and needed to be repaired to improve pedestrian crossing conditions, as it is explained in the report.

Time was also gained because in each model update, it was also possible to automatically extrapolate the 2D plans without having to modify them again, as it happens with the traditional methodology.

With this thesis, we also wanted to gather all the information about the elements that appeared in the project and to manage it with Pronic. With this platform, all the agents involved in the work had access to the material files, costs, measures, and also allowed the agents to intervene with their opinion about the different project phases, in order to consult or to change something.

The following case studies are projects that we found on websites:

3.5.4. CASE 4

The first one, made by the architect and professor of BIM Management Alejandro Núñez, who explains in his blog [55] how he was able to successfully install an elevator in a fisheye staircase of a building with 140 years old in one of the streets with more pedestrians of Barcelona (Passeig de Gracia) using the BIM technology.

This project was accomplished by initially doing a laser scanner of the entire building and, after, working with BIM to create the building virtually and introduce all the materials, installations and elements in the model. With this methodology we are able to:

- Set the budget of the work from start to finish. It was necessary to fulfill a very restricted budget (the work was carried out for less than 1,500 euros per square meter).
- Security, thanks to the control offered by BIM for having all the variables that exist in a design and construction.
- Provide an inter-relation of the architectural design with constructive and functional.
- Link the economical and architectural conditions with the automatic and immediate relationship between drawings, measurements and budgeting, being this last one a priority.
- Control the number of people in each plan, and if the relationship between these tasks, is appropriate at that time.

⁸ ProNic is a protocol that aims to standardize and to manage the technical information of the construction.

- Use the cradle-to-cradle criterion to create a "zero waste", which is the recovery of everything that is introduced at work can be reused and recycled when the building has fulfilled its purpose.

3.5.5. CASE 5

In April of 2018, with the coordination of the BuildingSmart Working Group and the collaboration of PetroBIM, ARESPA, HPLAB, [56] the Spanish conservation group, among other companies in the heritage sector, held a conference in the ambit of heritage conservation work, using the BIM methodology.

It was presented a practical case developed by PetroBIM, which is a company composed by a group of professionals whose objective is to make the Conservation of Historical Heritage and difuse it around the world.

This team uses the BIM system in their rehabilitation projects, as it allows to avoid errors and, therefore, it is more sustainable and effective system instead of to act when damages happen.

This method is also a success' guarantee in this sector, since it takes into account factors such as planning and execution of maintenance plans, the design of action protocols, quality controls and the commitments that all of this implies, focusing on sustainability.

Project: La casa de la Vall, Comarca del Bages Natural Park of Sant Llorenç del Munt and l'Obac. [57]

Because of the deterioration of a good part of the buildings of the farmhouse, and of the specifications of patrimonial cataloging of the building, the client decided to document the property and make its conservation using the BIM methodology, with the following scope:

- Survey with classical topography.
- Surveying with laser scanner.
- Roof orthophotogrametry using drones.
- Generation of native BIM models, with Revit v.2017.
- Publication of models to IFC 2x3 Coordination View 2.0.
- Generation of CAD / 2D documents of plants, elevations and sections.
- Conservation and rehabilitation of the building to get the property modeled from CAD / 2D files, and information management.

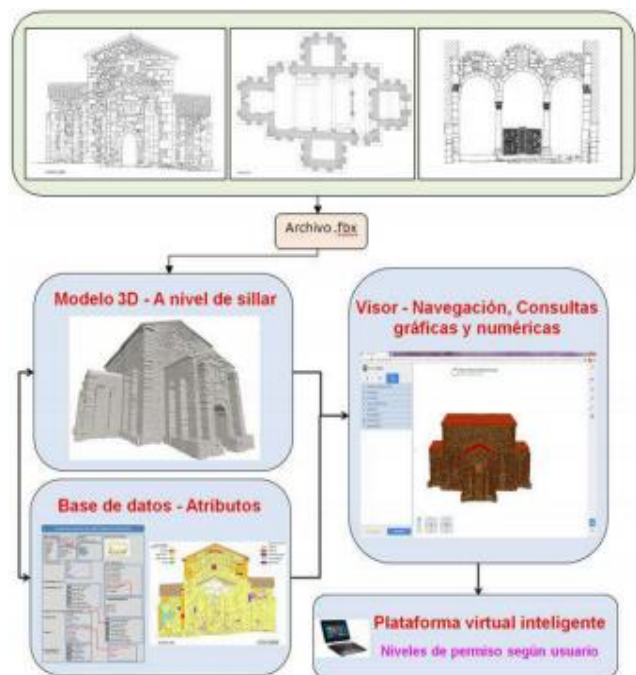


Fig. 26 Steps to reach a virtual 3D model from the plans [57]

BIM objectives for this project:

- Heritage Documentation. Get a current state of the reliable building
- Provide a baseline for structural analysis
- Once the model is achieved, use it as a reference for the rehabilitation project
- Have a base to extract metrics of elements for economic quantification
- Design the framework of a BIM system that should serve as a basis for the development of future projects in BIM.

When using BIM, a series of considerations were taken into account:

- I. For this project, modelling was carried out using the laser scanner, point cloud to extrapolate the information and obtain the model in the BIM file. First of all it is necessary to emphasize that a modelling is a simplification of the reality, with more or less details and that there will be a series of variations with respect to the original building therefore a series of tolerances will have to be accepted. In this case:

	Tolerances +/- (mm)
Principal structure	50
Surround (Facades, roofs and holes)	50
Non-bearing internal elements	50
Interior slabs	50
Decorative elements	50

Table. 6 Tolerances of the project



Fig. 27 Building obtained by laser scanner and using the point cloud **¡Error! No se encuentra el origen de la referencia.**

- II. Document all the reference objects to have all the information tabulated. That is, have a good model structure.

- III. Good organization in the deliverables of the project, for this project was carried out in the following way:

BIM DELIVERABLE	STAGE	FORMAT
Revit BIM Model	Existing conditions modelling	*.rvt files
IFC BIM Model	Existing conditions modelling	*.ifc files
Levantamiento Topográfico	Surveying / Scan	*.dwg files
Original Point Clouds	Surveying / Scan	*.xyz or *.pts files
Processed Point Clouds	Existing conditions modelling	*.rcs files
Scan Position Files	Surveying / Scan	*.dwg and *.PDF files
Recorrido Virtual a través de Point Clouds	Surveying / Scan	Trueview files
Ortofotogrametria	Surveying / Scan	*.jpg files

Table. 7 BIM deliverable

Summary of obtaining modelling:

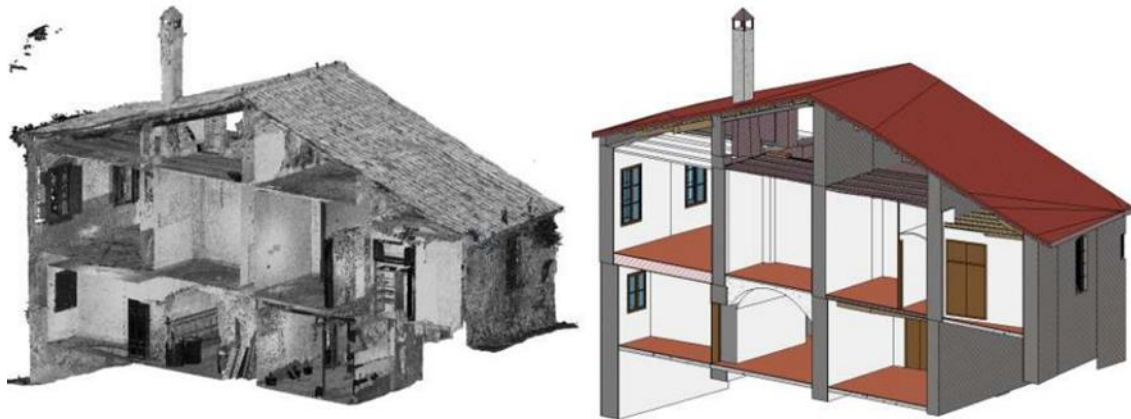


Fig. 28 Modeling obtained from laser scanner [57]

- IV. Once the modelling has been obtained, all the phases of the project are specified for its rehabilitation.

Advantages of using BIM in this project:

- Control and integrated data management to work with a single file. The model and the data are joined in the consultations;
- Easy to use visual environment, the 3D design allows you to have a better understanding of the building;

- All the professionals contributions involved in the different areas are stored in the same place. That way, time is saved in corrections and misunderstandings between them.

3.5.6. CASE 6

FC Barcelona also wanted to make a proposal to remodel the Camp Nou with the BIM system. David Cano, the project coordinator, highlighted the opportunities it generates, such as: [58][59]

- BIM as a large database;
- BIM as a tool, method and process;
- BIM as an As-Built continuous;
- BIM as a source for creating business;
- BIM as an organizational link between departments.

It is a project called "Espai Barça" and it aims to completely restructure the stadium, keeping part of its current structure and rebuilding the Palau Blaugrana and the Miniestadi.

The stadium is 60 years old and there has been some changes since the 1982 Cup. That way, a proposal was made to be one of the most complete stadiums in the world. It was decided to rehabilitate it and not to carry out a new work because they were looking for a proposal that would be an example of energy efficiency and environmental sustainability.

The reforms and the works accomplish for this project are all documented in the internet (in this Webpage, it is possible to consult if you would like to see future works).

Advantages guaranteed by BIM in this project:

- It requires very demanding planning, because the team must continue to play, and it is intended to have as little impact as possible on the members and the usual activity in the Camp Nou.
- In this way, the project risks are minimized, and the efficiency and sustainability of the whole process related to the project's life cycle is increased from the design, construction, start-up and future management of the building.
- It is expected to save up to 20% of the construction budget and more than 15% in annual economic management and maintenance with the use of BIM.
- Cost management of the entire project.
- Designing in 3D, using modeling programs such as Revit or Allplan, allows you to plan and to manage costs before the building construction, avoiding risks during the execution of the work. In addition, it allows the incorporation of a large database, with information on the entire construction process, in order to better manage all future buildings.

3.6. CONCLUSIONS CASE STUDIES

In all the practical cases that were explained, the advantages of using the BIM methodology for each of them were detailed.

With the use of BIM technology, we can draw several conclusions. The first, and most important, is that BIM is not just useful for new construction projects, but also for the rehabilitation of existing buildings, once it is possible to take advantage of all the potential and processes to make amide, autonomization of plans such as elevations and sections (generated and updated by modeling), data coherence, file segmentation ..., among others, and for union with environmental management programs, energy studies, lighting, installations, ...

This method also allows to have a good visual project control while working in 3D, which facilitates the understanding of complicated projects with the magnitude, and, in a virtual scientific environment, since everything is computerized.

So, with the virtual animation program, we can move around the building as if it were there and to make any variation to get what we want.

In addition, with BIM systems, the different stages of construction are rebuilt with material information and construction systems. This information focuses on a three-dimensional model and it allows a better comprehension of the building's behavior and a better action choice for the pathologies presented and needed in rehabilitation.

The use of the BIM system provides a smaller margin of error in the work, costs and time control, agility in projects' execution, and a collaborative environment and better coordination at work.

Above all, it allows us to anticipate errors and, therefore, reduce costs. But it is also a good tool for detecting conflicts between documents and reality.

In a conference of the College of Architects of Catalonia someone said an expression that summarizes the BIM perfectly:

“It allows to build before building.”

Moreover, one of the benefits of BIM modeling tools, such as Revit or Allplan, is the quick and easy development of graphic documentation for a project. This property of the BIM tools leads to a considerable reduction of time devoted to the elaboration of the graphic documentation and, above all, of subsequent and numerous modifications that are carried out until the project's final version.

It can be said, in a general way, that the use of BIM allows to extract and to elaborate documentation of greater precision and added value. Nowadays, through the traditional system, we continue to work with different separate documents, such as graphic documentation, memories and measurements.... With BIM, all information is available on the same platform, considerably reducing the possible inconsistencies that may exist in different documents.

Meanwhile, the time is optimized thanks to the ability to provide multiple uses to the same 3D model, within a collaborative environment.

As we said in the first chapter, where we explained what the BIM consisted of, we mentioned it as the main advantage the cost reduction and a more detailed control that is achieved by this type of methodology use.

There are several reasons why BIM is able to reduce costs, but the main reason is thanks to the ability to detect possible problems due to the simulation of the project's construction process. The works construction simulation is linked to a planning which allows to determine both constructive incompatibilities as well as the opportunity to perform tasks in a superimposed way. As well, a good study and development of the project in the design phase allows to anticipate problems that may occur later in the construction phase of the work.

Another of the uses is to address and to improve the energy efficiency of existing buildings through the use of BIM. According to data provided by the European Union, almost 40% of greenhouse effects are emitted by existing buildings. That is why countries such as the UK, the Netherlands, Denmark, Finland and Norway already require the use of BIM in construction projects financed by public funds. In the case of Catalonia, 2018 was defined for the mandatory use of public infrastructure and equipment projects with a value of more than 2 million euros, through the BIMCAT Manifesto that was presented at the BIM European Summit in 2015.

With the 3D model and the materials defined together with other data such as geographic location, temperature regime, winds, humidity, solar angle, systems used for heating / cooling, cost of raw materials, etc.), it can be made a prediction of the model's energy cost.

Having the ability to develop these analyses in the BIM model allows us to make very powerful decisions. We will be able to choose the solution that we consider appropriate by comparing the higher cost of the material, which implies a better insolation, in the future, in relation to the energy savings during the useful life.

In addition to the opinion of specialized professionals, all agree that the BIM methodology has a long ride ahead. Increasingly, the Spanish companies are betting on this system because they are satisfied with their results and are aware of its advantages.

4

EXAMPLE OF APPLICATION

In this section, based on a practical case provided by the university, personal conclusions will be drawn about the advantages of carrying out a rehabilitation with the BIM methodology compared to the traditional one. To carry out this study, the Revit program has been used.

4.1. INITIAL ASPECTS

The university has given me some plans in PDF about a rehabilitation carried out in a building located in the street: Rua de las Figueras (Malheríós-Maia). It consists of a 4-storey building, the first floor is for commercial use and has access to the apartments of the other floors. To access the apartments there are two differentiated areas with stairs that communicate with the apartments. Due to the lack of information provided, there is little information on the distribution of the plants. They only give information about those elements that need rehabilitation, therefore, the initial model that will be obtained will be rather a visual model of the existing building aspect:

- Floor 0 (Level 1): Access to the building, hall and machinery area.
- Floor 1 (Level 2): 4 apartments. In the plans only, the spaces with the furniture to be rehabilitated are distinguished as are the bathrooms and the kitchen.
- Floor 2 (Level 3): 4 apartments as those on the 1st floor.
- Floor 3 (Level 4): 4 apartments as those on the 1st floor.
- Cover (Level 5).

In the section of Annexes, you can see these Plans. When not having all the documentation of the work it was decided to invent any calculation / materials and even works to be done in this rehabilitation, using only the sketch of the building and taking advantage of some of the different reforms indicated in the plans acquired as a guideline. From this study, a series of conclusions about the BIM methodology and its benefits will be obtained in a small measure, since it is a theoretical project where no more personnel interact, it will not be possible to work on the entire methodology. The main characteristic of this methodology, which is the improvement in cooperation between members of a project, can not be seen firsthand. This will give us the conclusions about the modeling, the cost of the project and the different planes that can be extracted from the modeling. Highlighting the differences of using the Revit program in comparison to AutoCAD.

Objectives for this case study:

- Learn to use the Revit program, since I had no experience with this program. On the other hand, AutoCad I have learned to use in the university in different subjects and above all where I obtained more experience was working in a small engineer where I made the plans of facilities as student in practices.
- Draw conclusions about the advantages in the first person of the use of Revit against the Autocad program.

- Obtain an initial model to be able to generate and update the new model with the different reforms to be carried out.
- Make a budget for the work through the Revit mechanism.

4.2. STEP BY STEP CREATION OF THE MODEL

From the PDF files provided by the university, the first step is to make a model of the existing building and then apply the different reforms that are carried out in this project.

Since the starting information is a PDF file, the only way to deal with Revit, as discussed in chapter 2, is to convert this PDF file into an image, since Revit does not have the option to import PDF files directly. that in AutoCAD yes that allowed it.

Not having on my computer, the Adobe Acrobat program (commercial version) that allows converting the files to image formats such as JPG or TIFF. New ways of obtaining the files in image format were searched online. There are many free pages on the Internet that allow this conversion, although they do not recommend using it for security reasons. [60]

Once the image was obtained for each of the plans, they were imported into the Revit program. Once in the program, it was scaled by means of a tool that provides the program from an invented benchmark, since in the acquired plans there is no referenced benchmark.

Once the plans were scaled, a sketch of the building was made, tracing over the plans as shown in the following image:

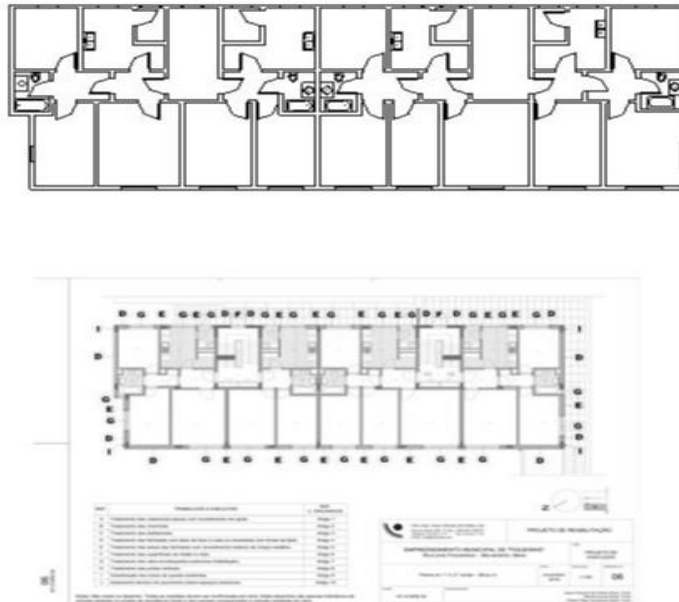


Fig. 29 Sketch obtained from the plane. (Revit Program)

After designing the plant (Level 2) a copy of it was made to get the remaining 3 floors since they are identical except the first level. To draw the first level floor, you can also take advantage of the perimeter of the reference floor (Level2).

Then the four floors were joined with two areas with stairs to access the different apartments. To do so, the gaps were drawn where the stairs will be designed and then with a tool that Revit has, the stairs are designed automatically, simply and above all very visual. In this way it was possible to make a model of the existing building as you can see below:

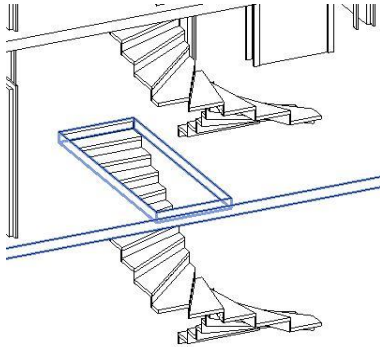


Fig. 30 Stairs of the model. (Revit Program Program)

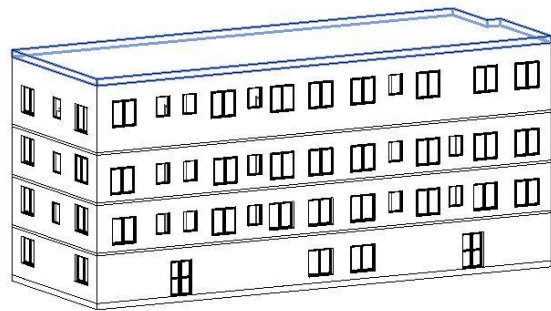


Fig. 31 Base model of the building to be rehabilitated (Revit Program)

Having no starting information of the existing building, this base model (Phase 1) did not refer any material since, what is interesting is to reference or visualize the rehabilitation reforms that will be carried out, where are you, which will be referenced with its properties (materials used, dimensions, manufacturer, model, costs ...) and distinguishing the different phases of the project.

It is important to delimit the project in phases because this makes it clearer what is existing building, what is demolished and what is new work. It is all more visual and, in this way, all the agents involved in the project can understand it better and thus avoid misunderstandings. For this project 3 phases were created:

- Phase 1: Existing Building
- Phase 2: Demolition
- Phase 3: New construction / Furniture

Next, we explain the different reforms that will be carried out in this project:

	Reforms
Level 1- Floor 0	<p>Demolition phase:</p> <ul style="list-style-type: none"> - A wall is demolished to get more space and create a space for commercial use. - 6 holes are made in the facade to put 5 doors and a window, since, there will be a new restructuring of this plant getting reduce the engine room to create 4 commercial spaces. <p>New Phase: 9 new walls are created to create the 4 commercial spaces.</p>
Level 2- Floor 1	<p>New phase:</p> <ul style="list-style-type: none"> - Installation and assembly of new sanitary furniture - Laying of new pavement - Laying of tiles in the bathrooms of the apartments - Paint all the internal walls of the apartments
Level 3- Floor 2	<p>New phase:</p> <ul style="list-style-type: none"> - Installation and assembly of new sanitary furniture - Laying of new pavement - Laying of tiles in the bathrooms of the apartments - Paint all the internal walls of the apartments
Level 4- Floor 3	<p>New phase:</p> <ul style="list-style-type: none"> - Installation and assembly of new sanitary furniture - Laying of new pavement - Laying of tiles in the bathrooms of the apartments - Paint all the internal walls of the apartments
Level 5- Floor 4	<p>New phase:</p> <ul style="list-style-type: none"> - Installation and assembly of new sanitary furniture - Laying of new pavement - Laying of tiles in the bathrooms of the apartments - Paint all the internal walls of the apartments
Cover	Treatment of the flat roof with a new coating.
Facades	<p>Exterior facade cleaning with new coating:</p> <ul style="list-style-type: none"> - Concrete block covering up to 3m height. - The rest of the façade cladding with triple hollow ceramic brick

Table. 8 Reforms of my practical case

Then, you can see the different phases of floor 0 (Level 1) differentiated by colors with the following image. The existing phase is marked in black, the knockout phase in pink and the new construction phase in gray. The advantage of this program is that you can work with the 3 phases at the same time, which are updated automatically as it is being demolished or creating new work. Therefore, you can see in a very visual way the improvements or changes that the building has received with the new reforms.

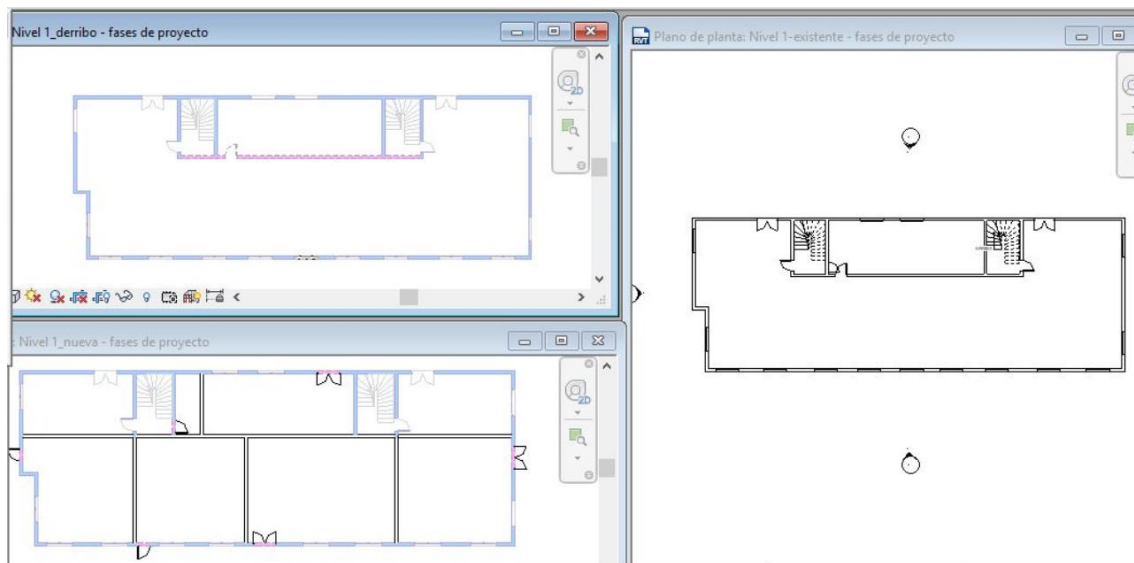


Fig. 32 Plans of the three phases of the 1st floor

Next, the sanitary furniture for the different floors was introduced. The Revit program has a built-in database with already designed blocks of all the essential elements of a building. In this way it is very easy, and you save a lot of time when designing the internal part of a building with its respective furniture.

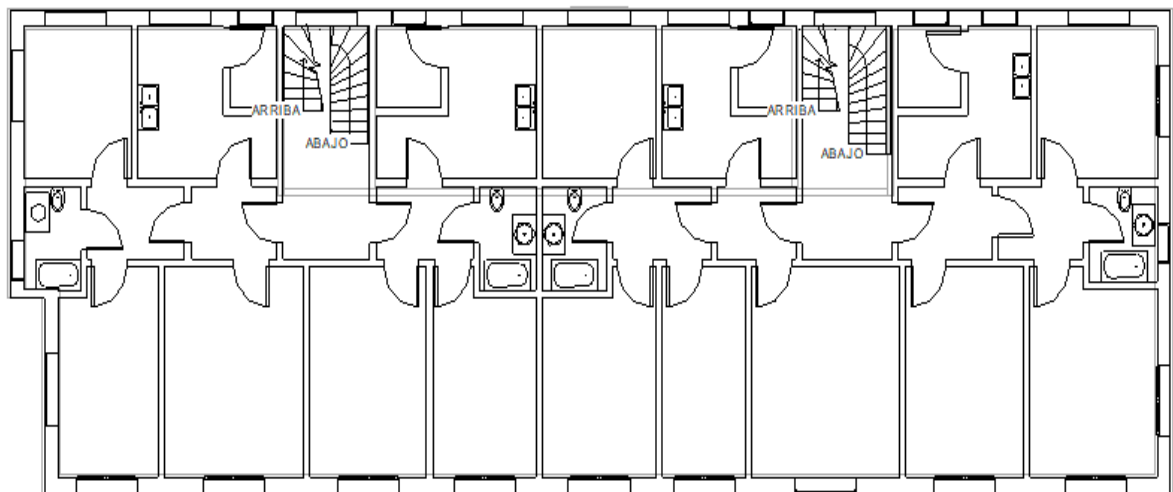


Fig. 33 Floor 1 with all the sanitary furniture

Next, all the elements of the model that were to be reformed were referenced:

- We introduce the characteristics of catalogs extracted by Internet of sanitary fittings, doors and windows. You will see in more detail in the section of costs where the manufacturer and model to be used will be specified.

Propiedades de tipo

Familia: Bañera-Rectangular con grifo-3D Cargar...

Tipo: 1200 x 700 x 498mm Duplicar... Cambiar nombre...

Parámetros de tipo

Parámetro	Valor
HWFU	
CWU	
Datos de identidad	
Imagen de tipo	
Nota clave	
Modelo	Contesa 170
Fabricante	Roca
Comentarios de tipo	
URL	
Descripción	
Código de montaje	
Costo	106.00
Descripción de montaje	
Marca de tipo	
Número OmniClass	23.45.00.00
Título OmniClass	Sanitary, Laundry, and Cleaning E
Nombre de código	
Otros	
W2	131.5

<< Vista previa Aceptar Cancelar Aplicar

Fig. 34 Sanitary furniture properties

- The interior and exterior walls and the cover with their respective coatings were indicated and referenced. To achieve that the exterior façade had two types of cladding: concrete block of the floor up to a height of 3 meters and brick cladding with the remaining height, an existing type of wall was published, specifying the two finishes and marking their distances. Here you can see the power that this program has since you can even add the different materials that you need depending on the façade for each project.

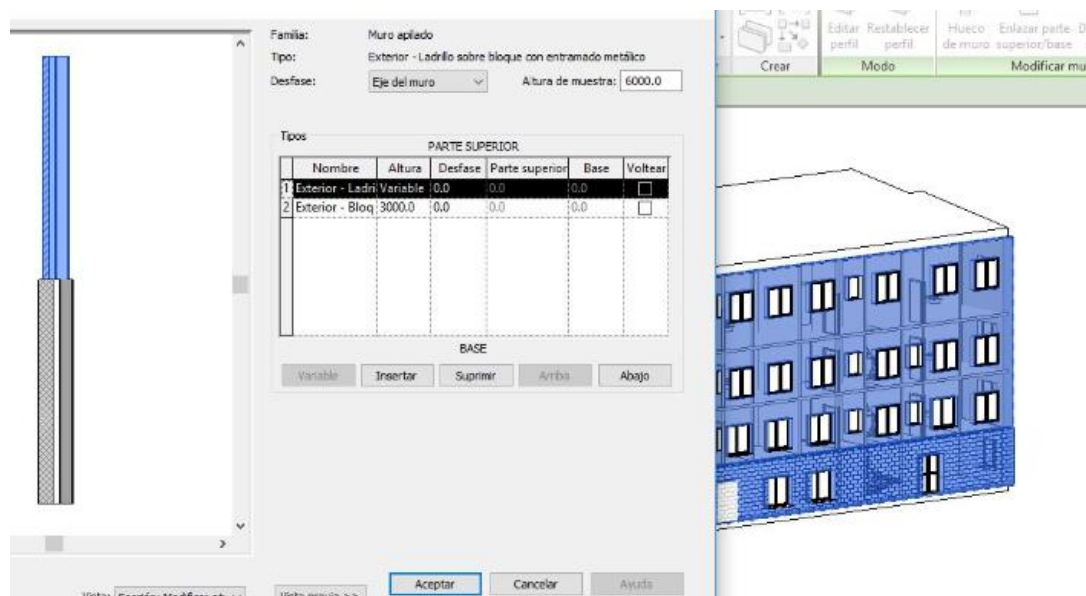


Fig. 35 Finished facade design

- The 4 pavements of the plants were created with their referenced material. Each of the plants is formed by the same stoneware floor. Which is an economical pavement, easy to clean and resistant to chemical attacks.

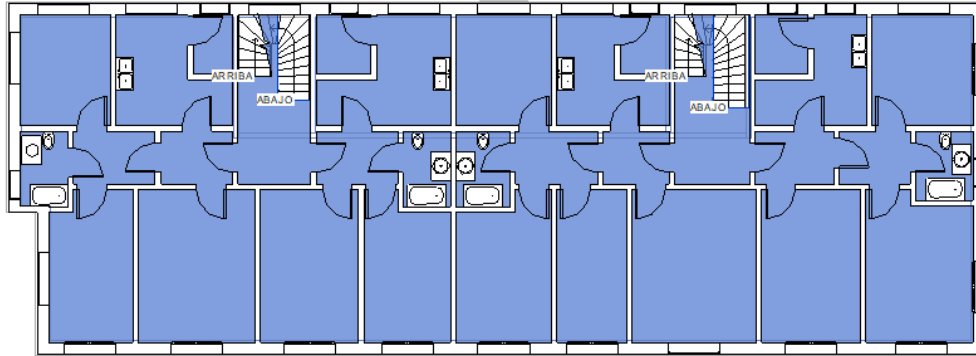


Fig. 36 Floor 1, pavement design

4.3. ERROR DETECTION TOOL

Then, some errors of the model were detected thanks to the 3D view, the windows were all unaligned and each located at different heights. Therefore, the windows for each level were equalized and a certain height was imposed with the aim of aligning all the windows to achieve this way, a building with better aesthetics. The default program imposes a certain height therefore it has to be corrected and equalized with the different types of windows, as can be seen in the following image:

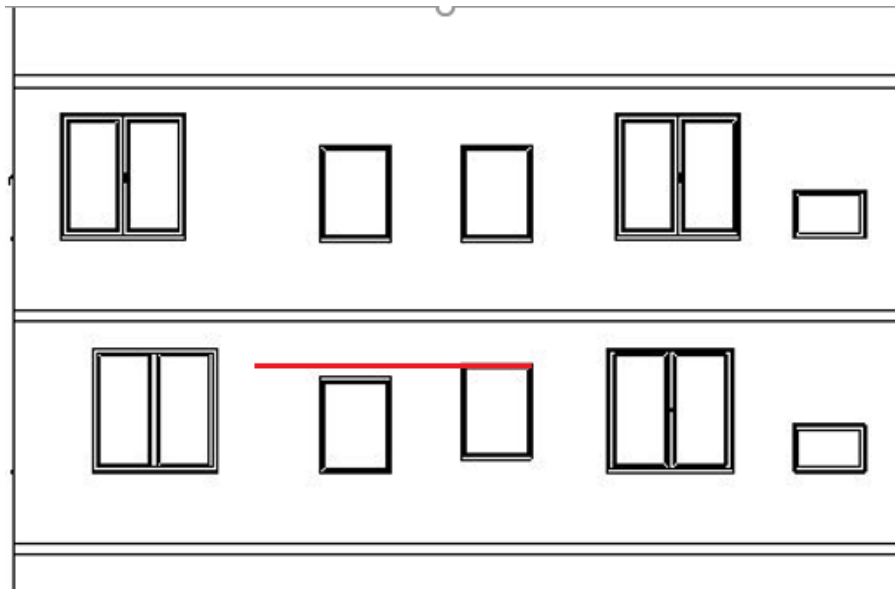


Fig. 37 Fixed elevation, alignment of the windows

The model was observed in detail and it was also detected that the internal walls of floor 2 did not reach the ceiling. Therefore, this tool can be used as an error detector as it has also been observed to equalize the windows. For this case that is shown as an example, the upper restriction of internal walls was not specified:

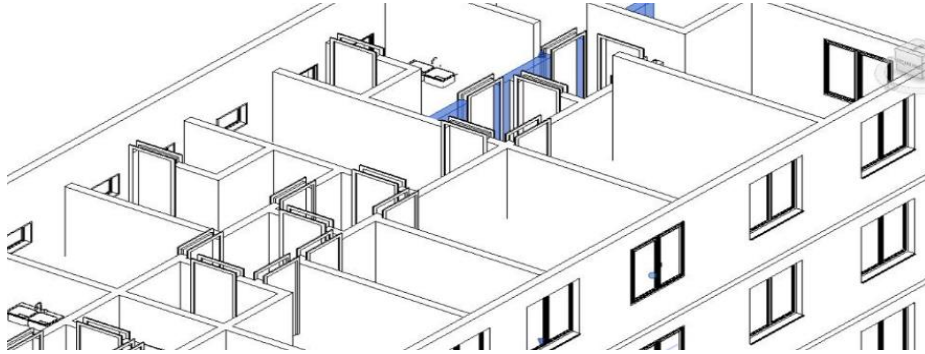


Fig. 38 Correction of internal walls

Finally, the final model is achieved with all the reforms visualized and with a very close aspect to the real one. This allows to visualize and better understand the final state of the project and detect or update those aspects that do not finish liking.

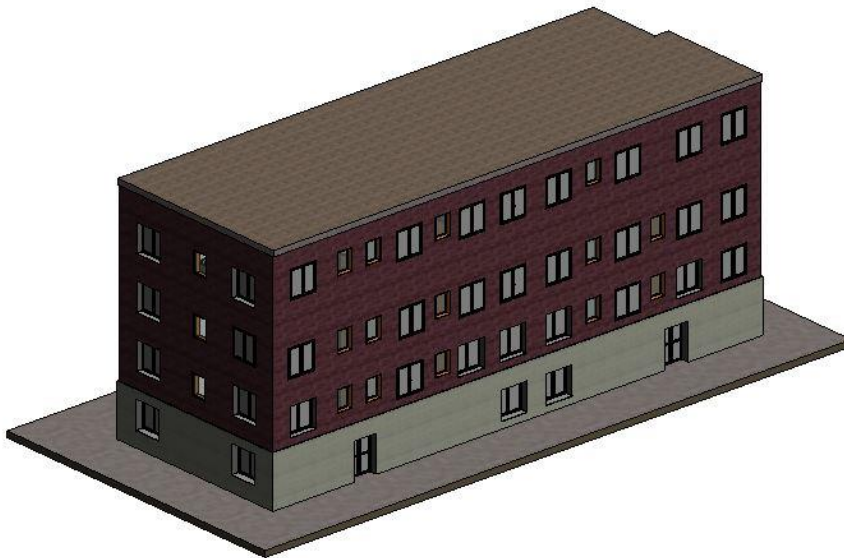


Fig. 39 Final model with all the reforms

4.4. COST OF THE PROJECT

The following describes the costs of the model with the main properties (width, height, manufacturer, model and cost) according to each family and type of model element. To this end, it has been specified in each element that needed a reform the materials with their necessary specifications from catalogs extracted by Internet. This is undoubtedly the longest and most boring part of the project, but necessary to make a budget for the work.

When carrying out this part once all the elements are referenced, the Revit program provides a tool that allows extrapolating a table with all the information of all the elements. You build the table with the information that you indicate previously, therefore, it is a table customized to the taste of the person who makes the project. For this case I have designed a table with the necessary information to make a good work budget.

In this budget I have encountered a series of problems especially in the counting of the different sanitary elements, windows and doors. For some reason, the program added more elements of the existing ones. After repeating the process several times, I came to the conclusion that the program did not distinguish the three phases of the project and therefore obtained three times as many elements. As I did not find a solution, I resorted to the traditional process of counting all the sanitary elements, doors and windows one by one.

Since most of the elements are the same, I was able to extrapolate the information of each element, saving me from re-entering all the information in Excel.

Revit presents the option to export all project data in various file formats. Therefore, all this information can be used to then work on structural calculation programs, energy programs and more elaborate cost programs. For this case, I have only exported the information from the tables to be able to work in Excel and perform the Excel tables shown below:

Cost windows								
Height	Width	Cost	Description	Producer	Model	Count	Phase	Levels
1600	1600	150,00 €	Windows of PVC Top 72	Finstral	TOP 72	15	Existing	Level 1
						1	Demolotion	Level 2
						1	New	Level 3
						22	New	Level 2
						22	New	Level 3
						22	New	Level 4
					Total amount	82		
					Total cost	12.300,00 €		
1220	915	100,00 €	Windows PVC Top 90	Finstral	TOP 90	-	Existing	Level 1
						-	Demolotion	Level 2
						-	New	Level 3
						7	New	Level 2
						7	New	Level 3
						7	New	Level 4
					Total amount	21		
					Total cost	2.100,00 €		
					Total windows cost	14.400,00 €		

Table. 9 Cost Windows. Catalogue [61]

Table of Furniture									
Sink									
Height	Width	Length	Cost	Description	Producer	Model	Count	Phase	Levels
155	490	1200	120,00 €	Sink of 2 stainless steel buckets and drain on the right	Roca	J	-	Existing	Level 1
							-	Demolotion	Level 2
							-	New	Level 3
							4	New	Level 2
							4	New	Level 3
							-	New	Level 4
							4		
						Suma Total	12		
						Cost T	1.440,00 €		
Handwatch									
160	370	550	300,00 €	FINE CERAMIC® wash basin from on countertop with fixing set. Includes drain with fixed plug open porcelain	Roca	Square	-	Existing	Level 1
							-	Demolotion	Level 2
							-	New	Level 3
							4	New	Level 2
							4	New	Level 3
							4	New	Level 4
							4		
						Suma Total	12		
						Cost T	3.600,00 €		
Toilet									
790	360	600	446,00 €	Complete wall-mounted compact toilet with dual outlet (Includes cup, inner feed tank and lid	Roca	Meridian	-	Existing	Level 1
							-	Demolotion	Level 2
							-	New	Level 3
							4	New	Level 2
							4	New	Level 3
							4	New	Level 4
							4		
						Suma Total	12		
						Cost T	5.352,00 €		
Bath									
498	700	1200	106,00 €	Built-in rectangular steel bathtub	Roca	Contesa	-	Existing	Level 1
							-	Demolotion	Level 2
							-	New	Level 3
							4	New	Level 2
							4	New	Level 3
							4	New	Level 4
							4		
						Suma Total	12		
						Cost T	1.272,00 €		
						Total furniture Cost	11.664,00 €		

Table. 10 Cost of Furniture. Catalogue [62] [63] [64] [65]

Cost doors								
Height	Width	Cost	Description	Producer	Model	Count	Phase	Levels
2134	915	200,00 €	Flat door veneered in natural pantographed oak wood.	Norma	PANTOGRAFIADA ROBLE	3	Existing	Level 1
						1	Demolotion	Level 2
						1	New	Level 3
						27	New	Level 2
						27	New	Level 3
						27	New	Level 4
					Total amount	85		
					Total cost	17.000,00 €		
2100	1400	450,00 €	It is a door ready to use, free of maintenance. Current design with side glass, with stainless steel bar. Their faces are covered with a sheet of steel foliate of PVC resistant to water and UV rays.	Oblak	Modelo 1188 Wengue	2	Existing	Level 1
						-	Demolotion	Level 2
						3	New	Level 3
						-	New	Level 2
						-	New	Level 3
						-	New	Level 4
					Total amount	5		
					Total cost	2.250,00 €		
2032	762	350	Glazing model, upper glazed panel, with aluminum counter glass. Insulation, polyurethane filler. Baked paint base.	Oblak	Línia Óptima-Modelo 2702	-	Existing	Level 1
						-	Demolotion	Level 2
						2	New	Level 3
						-	New	Level 2
						-	New	Level 3
						-	New	Level 4
					Total amount	2		
					Total cost	700		
					Total Doors cost	19.950,00 €		

Table. 11 Cost Doors. Catalogue [66]

To make the proposed walls as floors, the area of each of these elements is necessary. Previously, the convenient information was selected to create the table and this time the Area option was added, unlike the previous costs.

Thus, a wall table was obtained, distinguishing both internal and external, and with the information of each of them (Type of finish, Manufacturer, model, and cost per m²). For the case of the pavement to be the same for each plant was obtained a table with the areas of each level and with the only information of the desired pavement.

With the table of walls as pavements you can see the power of this program. Since, you save a lot of time in personally measuring each wall or floor area as it is done in AutoCad. Also, since everything is linked, if a box is selected from an element of the table, such as a wall, it will appear differentiated blue in the model. At any time you can identify any element of the project. This allows you to correct errors or detect them very quickly.

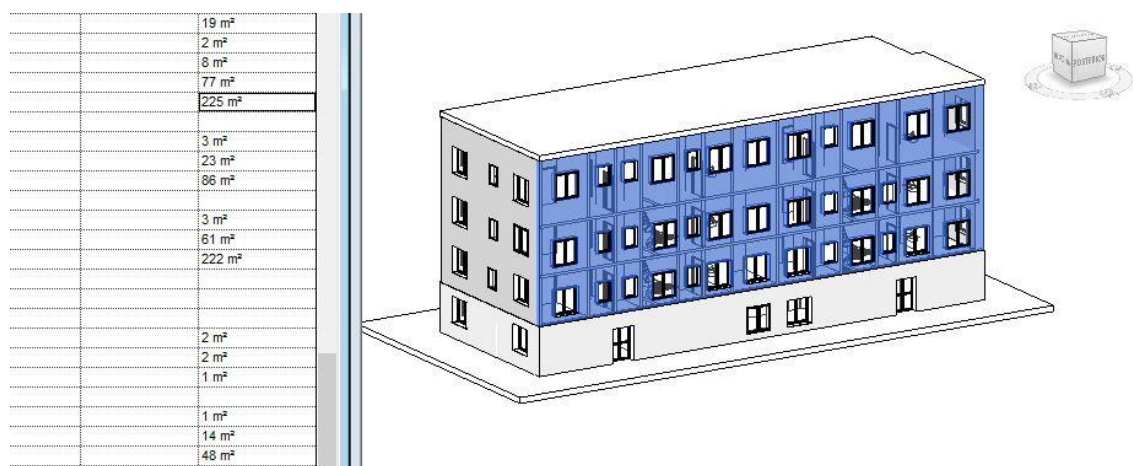


Fig. 40 Potential of the Revit program, select an area and indicate to which wall it corresponds

Wall and pavement table are shown:

Wall planning table						
Family and type	Works to be done	Producer	Model	material/ m2	Area	Cost
Basic wall: Interior - blocks 140 mm	Painting interior walls	Benjamin Moore	ben WATERBORNE INTERIOR FLAT FINISH WHITE- White Color	2,00	1572	3.144,00 €
Basic wall: Exterior - Concrete block	New lining with concrete block	UNE-EN 771-3	Exterior facade enclosure sheet, 10 cm thick factory, hollow concrete block, for coating, gray color, 40x20x10 cm, standard resistance R10 (10 N / mm²), received with industrial cement mortar, gray color, M-5	21,35	198	4.227,30 €
Basic wall: Exterior - Brick	New hollow ceramic brick cladding	UNE-EN 771-1	Triple hollow ceramic brick, for coating, 33x16x11 cm, received with industrial cement mortar, gray color, M-5.	20,87	614	12.814,18 €
Internal wall - washbasin area	Finishing walls with Tiles	Bañoldea	Baldozer-CANAPA AZULEJO 20X50	9,00	91,2	820,80 €
					Total Cost	21.006,28 €

Table. 12 Cost wall planning table. Catalogue [67] [68] [72]

Floor planning table					
Family and type	Producer	Model	Level	Area	Cost
Floors: Generic 150 mm	Bricomart	PAVEMENT GRES 45 X 45 CM CAMPUS GRAFITO	Level 1	304	1.809,01 €
Floors: Generic 150 mm	Bricomart	PAVEMENT GRES 45 X 45 CM CAMPUS GRAFITO	Level 2	304	1.809,01 €
Floors: Generic 150 mm	Bricomart	PAVEMENT GRES 45 X 45 CM CAMPUS GRAFITO	Level 3	304	1.809,01 €
Floors: Generic 150 mm	Bricomart	PAVEMENT GRES 45 X 45 CM CAMPUS GRAFITO	Level 4	304	1.809,01 €
				Total cost	7.236,06 €

Table. 13 Floor planning Table [69]

To finish, all the previous costs were added, and the price of assembly and disassembly of sanitary elements was contemplated, such as the cost per m2 of painting all the internal walls and the cost of changing the pavement of the 4 floors. In all the costs obtained, the labor price is already included.

This way you can extrapolate the total cost of the work:

		Description	Price	Nº of elements/Area	Cost
Furniture	Sink	Price disassembly and placement of new	175 For element	12	2100
	Handwatch	Price disassembly and placement of new	175 For element	12	2100
	Toilet	Price disassembly and placement of new	175 For element	12	2100
	Bath	Price disassembly and placement of new furniture	175 For element	12	2100
Pavement	-	Clean the old pavement and laying the new	12,8 for m2	1216	15564,8
Scaffolding rental for exterior wall cladding	-	Rental, during 15 calendar days, of standardized tubular scaffolding, multidirectional type "ATES", up to 10 m of maximum working height, formed by tubular structure of hot galvanized steel, 48.3 mm in diameter and 3.2 mm thickness, without duplicity of vertical elements, composed of working platforms of 60 cm wide, arranged every 2 m in height, internal staircase with trapdoor, rear railing with two bars and skirting board, and front railing with a bar; for the execution of facade of 250 m².	992,36 for 30 days		992,36
total door cost	-	-	-	-	14.400,00 €
total window cost	-	-	-	-	19.950,00 €
total furniture Cost	-	-	-	-	11.664,00 €
Total floor cost	-	-	-	-	7.236,06 €
Total wall cost	-	-	-	-	21.006,28 €
				Total Cost	€ 99.213,50

Table. 14 Total cost of the project. Catalogue [70] [71] [73]

4.5. COMPARISON BETWEEN REVIT AND AUTOCAD.

Below are the advantages I have observed when using the Revit program to obtain my model. Logically, as you get to know more about the program and know more tools available, you can quote many more.

The advantages that I have found personally when working in Revit compared to the AutoCad program are the following:

- It allows to work in 3D from the beginning. The moment you create a wall, the 3D view appears. This allows to better understand the model that is being created.
- You can work with a large number of views at the same time to better understand the design. One of the properties of Revit is that if in one of the views you point to a wall, it automatically marks it in all the views. This allows to better identify each one of the parts of the model.
- When working in Phases they are automatically updated and differentiated by means of colors to distinguish the phase of work in which the plane is located. This allows to visualize in detail the different updates that are made during the design phase making it clear that elements are part of the existing building, demolition or new work.
- It allows to reference each element that appears in the model with all its properties, this allows it to be easier when obtaining the table of quantities and costs of the reforms. Unlike the traditional system with AutoCAD where you have to go counting all the elements that appear manually, being a slow and imprecise technique.
- It allows to obtain a table with all the elements that appear in the model specifying its characteristics, properties and cost.
- By working in 3D, you can detect errors and solve them quickly. In my case I could correct the height of the windows and match them in a very short time, which in AutoCAD would mean repeating the plane again.
- There is a database with many elements already designed. This allows you to design the internal part of a building more quickly than AutoCAD. Also, all the elements are more easily coupled, for example, when entering a window, it is already correctly adhered to the wall and you do not have to create a space to insert the created window block afterwards.
- When creating stairs is easier than in AutoCAD, which you have to create each one of them from 0. With the tool available Revit, you can enter all the characteristics of the ladder you want with its characteristics and limitations and if it is Viable automatically creates a ladder with the specified specifications.
- Allows the creation of internal, external walls and pavements with the desired specifications. You can create each of them from 0, imposing all the materials that make them up as well as using already created models stored in the Revit library.
- As you design if the program observes something that is not viable, you receive a warning. Therefore, it is easier to detect errors than in AutoCAD.
- Creation of plans at the moment, if the model is modified it is updated at the moment and therefore planes are always available with the last update. This is a great advantage with respect to the traditional system, since changing something meant repeating a plan again.
- Allows you to observe the model with great detail and realism in this way you can have a very clear and precise idea of how this new renovated building will end.
- Revit presents the option to export all project data in various file formats. Therefore, all this information can be used to then work on structural calculation programs, energy programs and more elaborate cost programs. For this case, I have only exported the information from the tables to be able to work in Excel.

Disadvantages that I observed from Revit:

- You cannot import PDF files directly unlike the AutoCAD program that did allow this option. This causes you to have to start from an image that when imported causes the program to slow down a lot when performing its functions.
- You need to reference each element of the model. When making the costs, it is necessary to spend a lot of time in editing each type of family of elements and introducing their properties and cost.
- When you create tables of quantities when recounting the sanitary furniture, number of doors and windows does not calculate it correctly. I think it is due to the different phases of the project, the program adds both all the elements that appear in the existing phase and new work giving the wrong result.
- In the 3d model, new construction doors and windows are not displayed and I have not found a solution.
- It takes practice and dedicate time to exploit the full potential of the program.

4.6. BENEFITS OF USING THIS METHODOLOGY FOR THIS CASE STUDY

The complicated thing about the new methodology is to obtain the model, but, once it has been achieved, all are benefits. For example, for this case, a study could be made quickly on the different types of cladding for the facades. You just have to carry out a study with several finishes and select the one you like the most, either for aesthetics or cost. For both cases with this program is achieved very quickly because, with the 3D model shows the building in a way very close to reality so if you want to select a type of finish for its aesthetic is very simple. In the same way, it passes according to whether it is preferable for its costs, since once determined several finishes, each of them is referenced with their respective information and a cost table is extrapolated as those obtained previously.

Moreover, there are numerous complements that can be used with Revit once the model is obtained, as can be seen in chapter 2 according to the results you want to obtain (Plugins):

For example, if a more detailed budget is preferred, there is the Cost-It program [74], which allows a budget to be made from all the model information. By other hand, there is Vray [75], it allows to obtain a fast and high-quality project visualization, from simple models to the most complex ones. There is also, Aplicad CTE HULC [76] that obtain the energetic certification of the building through the model obtained by Revit.

This type of applications allows a lot of time reduction, since, for each type of tool, all the model information had to be inserted from 0.

5

CONCLUSIONS

After the extensive study and analysis of the BIM methodology, now I am able to answer the question that encompasses this final Master project. Is it beneficial to use the BIM methodology in rehabilitation projects compared to the traditional methodology?

My answer is yes, although the implementation will be slow because, like any change, people are reluctant to them. As has been seen throughout this project, this new way of working on architectural and engineering projects is becoming increasingly important. It is a change of philosophy when carrying out projects that affects all the agents participating in it. The new methodology supposes a greater cost at the moment since this type of technology needs to be implemented and this demands changes, adjustments, norms, softwares that provokes the increase in the methodology.

There are a large number of internet pages, articles and magazines that speak of the advantages that BIM represents as it has been seen in the first chapters of the project. The main one is that it anticipates future mistakes since with BIM a virtual model is obtained that contains all the information of the building and that thanks to that you can know problems before manufacturing or buying anything ...

Currently, the biggest problem of buildings and construction in general, are the "unforeseen". That many times, they simply lack foresight. As a solution to these unforeseen events, this BIM methodology is born, which allows for more information, more quantifiable data of the building. And the more data we can give the project, we can get more accurate information and closer to reality.

This virtual model can anticipate future events, and therefore future errors can be saved by saving costs, since it is not the same to correct the model from a computer than in the same work, which involves a higher cost of money.

The main difference with the traditional methodology is that it gives top priority to the information. Many times, with the traditional system the final cost of the project is more expensive than expected and several times is because the company or person who calculated it, did it wrong. It did not take into account all the data, did not take into account all the necessary information unlike this new methodology.

In any case, the BIM serves to better manage the design and construction of a building. And thanks to good management saves money. There are studies that show that more money is saved with the new methodology and everything is possible thanks to the fact that it handles more data.

Throughout the project, the advantages that BIM presents in both new and existing buildings have been mentioned. The first months of work that have been research I have obtained a theoretical idea of what the implementation of this new technology, exposed in the first chapters.

Having worked in a small engineering company in Barcelona last year, where I was doing plans for the installations of different buildings, it has been easier for me to observe or identify the weakest points of the traditional system and the advantages that the change in methodology can bring.

As I mentioned in the previous chapter, I have been able to personally appreciate the potential of BIM, to a lesser extent, since I focused on the design phase of a project: the creation of the model and all the

information that can be extracted from it.. The experience has been positive, and I could see what this new methodology is able to offer and get to know the many benefits that BIM can bring in a global project.

All these benefits are discussed throughout the project where the most notable are the following:

- BIM has all the information in one platform, reducing considerably the possible inconsistencies that may exist in the different documents. At the same time, time is optimized thanks to being able to give multiple uses to the same 3D model, within a collaborative environment.
- Visualization of the 3D model of a building that has to be rehabilitated / restored helps to make better project decisions on aspects such as volumetric, distributions, structural strategies, facilities, materials, budgets and work phases.
- This methodology allows to increase productivity, which in this sector, as commented at the beginning of the project, was one of the lowest. It saves time in several fields: the first as a tool to detect errors, since its 3D visualization allows to better understand the design and identify more easily possible inconsistencies. Also, when plans are modified, they are updated automatically unlike the traditional system where you have to repeat them. It also reduces time by having all the elements of the model documented, since it allows you to extrapolate tables with all the information of the model you want automatically.
- The elements that are represented have physical properties: materials, finishes, prices, ... In addition, the properties are stored in relatable databases, making it very easy to generate all types of reports.
- There is an interoperability format between BIM programs, which allows easy translation from one program to another.
- It allows to check interferences between models (architectural, structural, installations) before starting (and during) the work, which avoids problems and expenses.
- The BIM facilitates communication with the different agents involved (developers, planners, builders, industrialists and maintainers) and the understanding of the scope of the work, direct measurements, viewing of project options, etc.

As unfavourable parts to be introduced in BIM we can point out the following points, where the majority corresponds to the high investment that has to be made to train all the staff and prepare the company with the appropriate devices that allow the best use of this type of technology:

- High training for all personnel or agents involved in the project. The presence of BIM Managers is needed to manage the teams and coordinate the work. It is necessary to train the work teams in the operation of the BIM programs.
- In general, you need to invest a lot of money in new software licenses and surely in new hardware. The programs that use BIM, usually need very modern and powerful computers since with computers without so much capacity it can cause blockages of the program or also a slow execution of this.
- In the beginning, in a company that joins the BIM, it is highly recommended to create templates and internal work standards that facilitate coordination and teamwork.
- The work must be collaborative. The work between the different departments and companies involved from the beginning in the project must have as objective collaboration and concurrent engineering. In the beginning this can be seen as an inconvenience, since you have to make sure that all the parties involved want to use this methodology. When companies start to see the advantages of BIM and every time there are more companies that trust and therefore this new technology is complemented mind implemented, this section will see it as a benefit.

- It is convenient to define more parameters before starting modeling. In addition, it is very difficult to get all the families we need for a specific work.
- The difficult interoperability associated with it, this is quite noticeable when there are software preferences for different specialties. So the architecture, like each of the other design specialties, usually uses completely different softwares, which often appear many errors on the way and at the end of the process when these models come together.
- Another limitation associated with BIM refers to the fact that its terminology may contradict that used in traditional CAD processes. BIM requires familiarization with a set of expressions, phrases and nomenclatures unknown to professionals working with CAD. Therefore, during the transition period there may be different interpretations and even deceptions between the different works and projects.

The migration process will be slow at first, but then it will develop exponentially, just as it happened when the CAD was replacing the manual delineation. As we have seen, after reviewing the most advanced countries looking at the current status of the BIM and how these countries have standardized and standardized their use, it seems that both Spain and Portugal in a short period of time will be able to implement this new methodology, since which is becoming more and more forceful and many conferences are being held in this regard.

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